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Formation and Evolution of Pleistocene (MIS 5e) Strandplain Grainstones along the Leeward Margin of West Caicos Island, BWI

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Formation and Evolution of Pleistocene (MIS 5e) Strandplain Grainstones along the Leeward Margin of West Caicos Island, BWI

by

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Thesis

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Dedication

To Leon, Joe, Lynn, Lucille, and Mary Ann

Acknowledgements

I would like to thank my friends and family, for their constant encouragement and gusto. In particular, thank you to my dad, mom, brother, and two grandmothers for their love and late night conversations over the phone.

Thanks to the Reservoir Characterization Research Laboratory for the support of my project—without which, none of this work would have happened. I would like to extend various thank you's to my group members. Thank you Ben Smith, for always telling me when I'm not working hard enough, and thank you to Kris Voorhees, for always telling me when I am working too hard. Thanks to Kyle McKenzie, for the late night hysterics, and for always showing me the way to the reef crest. Thanks to 5th year PhD student, Greg Hurd, for providing sage advice in times of need. Thanks to Yawen He, for your intelligent assistance and constant politeness. Thanks to Nate Tinker, Andrea Nolting, Yaser Alzayer, and Chris Zahm for not only being talented structural geologists, but for providing structural support and advice for me throughout these last 2 years.

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Abstract

Formation and Evolution of Pleistocene (MIS 5e) Strandplain Grainstones along the Leeward Margin of West Caicos Island, BWI

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The University of Texas at Austin, 2016

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The island of West Caicos is a typical Caribbean Pleistocene-Holocene carbonate strandplain system that developed by accretion of successive dune-foreshore-upper shoreface intraclastic-peloidal-oolitic limestone grainstones. Although strandplains are the most volumetrically significant element of low-latitude carbonate island interglacial highstand deposits, documentation of the 3D facies architecture and accumulation rates for these basic building blocks is sparse. This detailed mapping project documents for the first time on the Caicos platform the timing and origin of a foreshore-upper shoreface ooid grainstone body along the west coast of West Caicos. Timing has been constrained for this grainstone body to the latter portion of the composite Marine Isotope Stage (MIS) 5e signal (5e_2), providing very tight constraints on duration (2-4 ky) and sea level history; there was a rapid rise from near present sea level to +6 m, which lasted from 121-118 kya. Subsequently, deposition ended with a rapid fall to -60m by 5d time (118-110 kya). Using these age constraints and high-resolution airborne LIDAR mapping, this

study analyzes vertical and 3D rates of accumulation, discrete facies architecture, provenance, and transport for this MIS 5e_2 strandplain.

Dip-oriented 2D cross sectional mapping across the 9 km north to south length of the west coast outcrops was carried out at 3 locations, and several 3D facies models were made. These maps fit into the larger regional map of the west coast MIS 5e and are enhanced with paleocurrent data from longshore-directed trough-cross-strata and foreshore strata. Across the profile, 53 thin sections document grain types, size, and sorting. The profiles consist of 3-6 degree dipping foreshore strata with dip widths of 10-20 m and plunge zone to upper shoreface facies with trough-cross-strata showing a distinct southward transport direction. Along the northern section of the profile, massive bioturbated lower upper shoreface grain-dominated packstones are present down dip from the upper shoreface. These massive grain-dominated packstones accumulated to 1 m thick, occur in greater than 2 meters of water depth, and rest locally on top of corals of the 5e_1 reef system.

The rise to a sea level six meters higher than present during MIS 5e_2 time increased ooid production on the Caicos platform and throughout the Caribbean (Kindler and Hearty 1996). Although a large amount of ooids were likely winnowed off the platform top due to prevailing easterlies, many of the ooids were transported from north to south along the leeward coast of West Caicos via longshore drift. This interpretation is supported by a unidirectional southward paleoflow direction, decreasing lateral (along-strike) continuity in 5e_2 grainstone units from north-south, and the poorly sorted nature of grain type in the petrography from north-south. The heterogeneity in grain type suggests a fair amount of grain mixing, indicative of transport over several kilometers; active ooid factories on West Caicos such as Ambergris and Long Bay Beach have >90% ooid compositions, much greater than ooid compositions along the leeward margin of West Caicos. Assuming a 3 ky period of deposition, vertical accumulation rates for this MIS 5e_2 strandplain are as large as 2 m/ky (6 m total), and 3D accumulation is 115,000 m^3/ky (345,000 m^3 total). Understanding the depositional and accumulation history during sub-Milankovitch sea level fluctuations underscores the stratigraphic complexity of Pleistocene icehouse systems, and shows short-lived rises in sea level can have significant effects on sediment production and carbonate island building.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

Pleistocene outcrops of Marine Isotope Stage (MIS) 5e age (Kindler and Meyer 2012) along the leeward (western) margin of West Caicos show exceptional facies variability along strike (North-South). Diagnostic facies assemblages along the leeward coast transition from predominantly intraclastic-peloidal-oolitic strandplain grainstones in the north to reef-dominated facies assemblages in the south (Kerans et al. 2015). Upon close examination of distribution, growth morphology, and stratigraphic relationships, these two units have been assigned to separate substages within the MIS 5e; the leeward coast strandplain grainstones occupy the latest part of the MIS 5e highstand (MIS 5e_2), between 121-118 kya (Kerans et al. 2015).

Exceptional outcrop and the extensive, lateral continuity of the strandplain grainstones make the leeward coast of West Caicos an ideal setting to closely examine a single, conformable strandplain unit with constraints on timing and geographic extent of deposition. The strandplain accumulations of dune-foreshore-upper shorface skeletal-peloidal-oolitic grainstones are the most volumetrically significant element in Pleistocene-Holocene carbonate island formation (Aurell et al. 1995; Garrett and Gould 1984; Hearty and Kindler 1993; Hearty and Kindler 1997; Mylroie and Carew 2008). As the fundamental building blocks for these carbonate systems, understanding the detailed timing, accumulation, and depositional architecture of a single strandplain unit lends insight into the overall formation and evolution of low latitude carbonate islands. The purpose of this study is to document the 2D and 3D architecture, formation, evolution, and accumulation rates of the Pleistocene MIS 5e strandplain grainstones along the leeward coast of West

Caicos through analysis of facies variability in several representative cross sections, paleocurrent data, petrographic transects, and volumetric measurements of three-dimensional geobodies.

GEOLOGIC SETTING AND BACKGROUND

The Caicos platform is a shallow water carbonate platform located north of Hispaniola and southeast of Great Bahama Bank between 21 and 22 degrees latitude (Fig. 1). West Caicos is a 9 km by 2.5 km carbonate island situated along the steep, leeward southwestern edge of the Caicos platform.

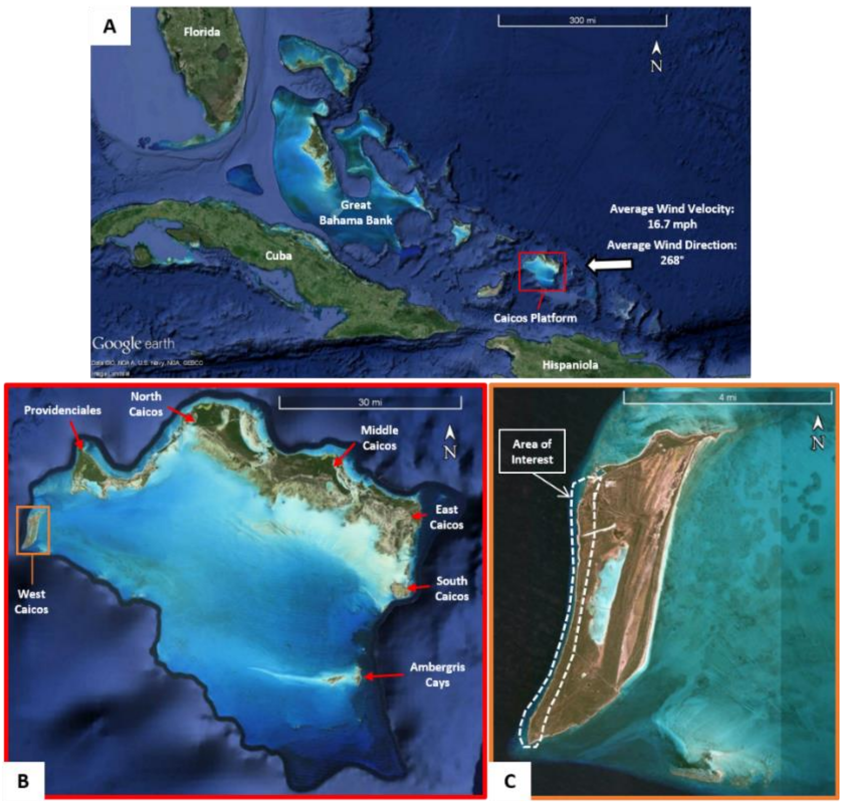


Figure 1: Geographic setting of West Caicos. 1A) Google Earth image of the Caribbean, emphasizing the location of the Caicos platform in relation to Great Bahama Bank and Hispaniola. 1B) Google Earth image of the Caicos platform, emphasizing the westward, leeward location of West Caicos on the platform. 1C) Google Earth image of West Caicos, emphasizing the area of interest for this study.

Prevailing easterly winds influence platform-top currents and associated cross-platform transportation of sediment. West Caicos is predominantly comprised of wind and wave-driven strandplain grainstones (Kerans et al. 2015; Simo et al. 2008; Wanless and Dravis

1989). The leeward coastline of the island is an assemblage of exceptionally exposed Pleistocene ooid grainstones; these outcrops are four to six meters above present day sea level, reflecting the MIS 5e sea level highstand (Hearty et al. 2007; Waelbroeck et al. 2002).

Throughout the previous 800 ky, relative sea level has been fluctuating on 100 ky cycles, with each major transgression and regression marked as a marine isotope stage (MIS) (Lisiecki and Raymo 2005; Sosdian and Rosenthal 2009). Figure 2 shows the relative sea level throughout the previous 450,000 years (Waelbroeck et al. 2002).

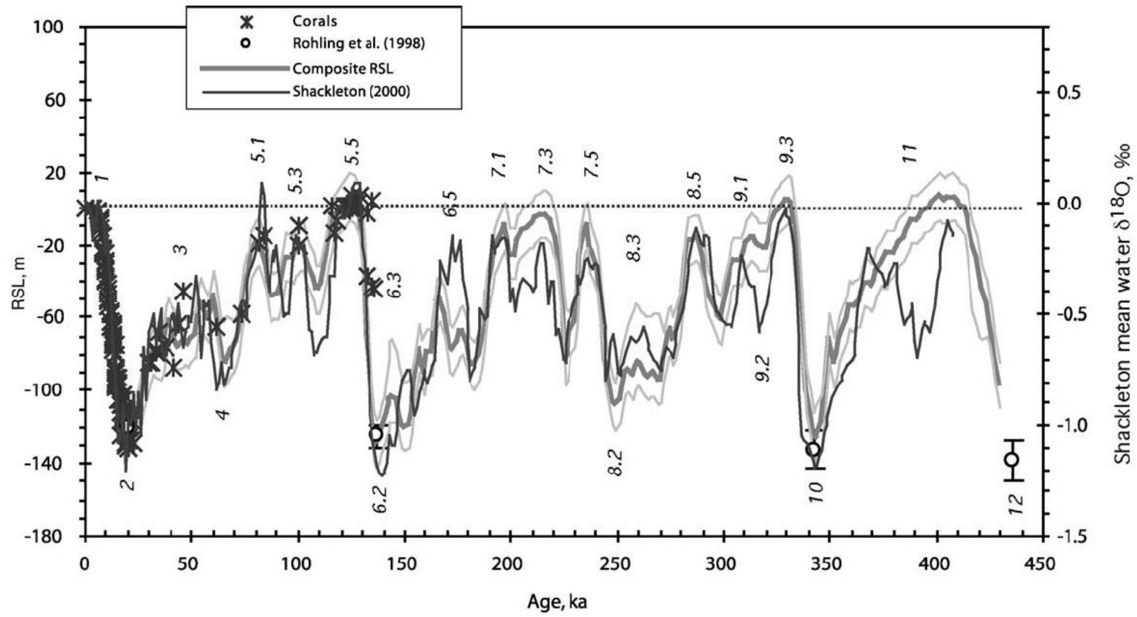


Figure 2. Approximate sea level throughout the previous 450 ky from Waelbroeck et al. (2002). The left axis represents relative sea level, while the right axis represents mean water $\delta^{18}O$ from Shackleton (2000). Deposition on low latitude carbonate platforms occurs during sea level highstands, notably the MIS 11, 9, 7, 5e (5.5), and 1. These highstands are labeled on this curve, with some split up into substages; most notable for this study is substage 5e (5.5).

West Caicos is an amalgamation of aeolian and subtidal grainstones, reefs, and salinas deposited throughout the most recent sea level highstands—most notably MIS 11, 9, 7, 5e, and 1 (Kerans et al. 2015; Simo et al. 2008; Waelbroeck et al. 2002; Wanless and Dravis 1989). Similarly to West Caicos, numerous other Pleistocene carbonate islands are amalgamations of subtidal and aeolian grainstones, and have subsequently been mapped according to their age or marine isotope stage. These include islands such as San Salvador (Hearty and Kindler 1993; Mylroie and Carew 2008), New Providence (Aurell et al. 1995; Garrett and Gould 1984; Hearty and Kindler 1997; Reid 2010), Eleuthera (Hearty 1998;

Kindler and Hearty 1997), Lee Stocking Island (Kindler 1995; Kindler and Hearty 1997), and Bermuda (Hearty 2002; Hearty and Vacher 1994; Rowe and Bristow 2015).

Earlier work on West Caicos suggests a pre-5e island core, with leeward margin longshore currents sourced from the north and south as the mechanism of deposition for the leeward margin grainstones (Fig. 3) (Wanless and Dravis 1989). With better constrained age dates, Simo et al. (2008) also emphasized a pre-5e island core with grainstone ridges prograding east, against the prevailing wind direction (Fig. 4).

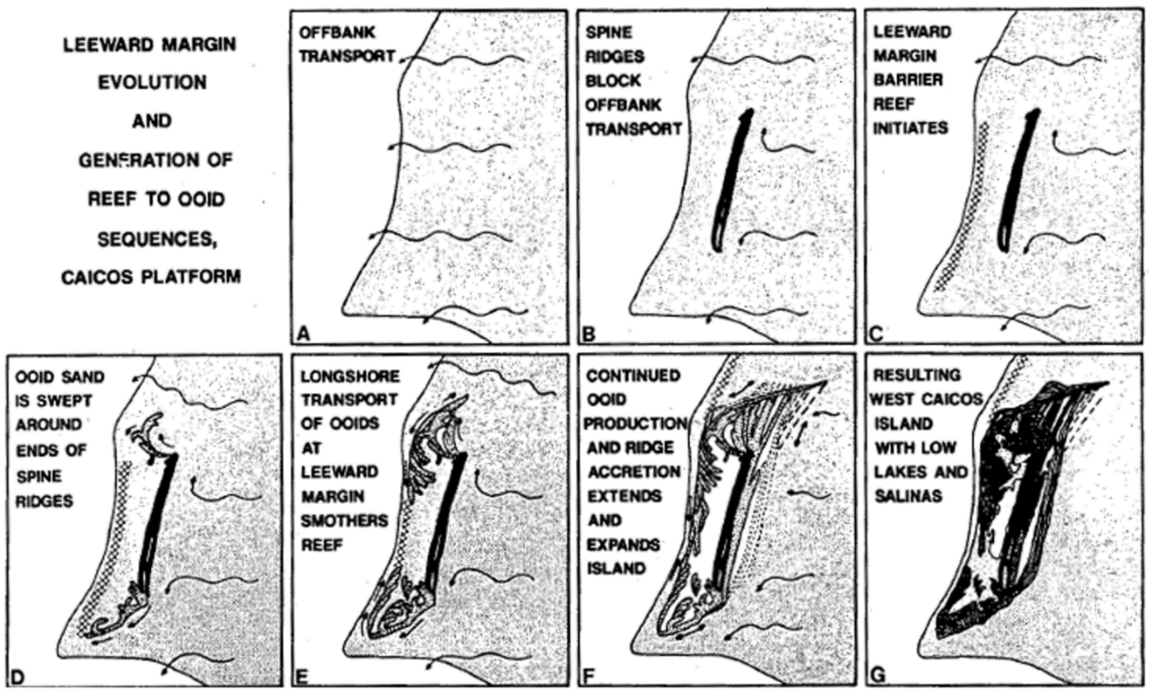


Figure 3. Diagram from Wanless and Dravis (1989) showing proposed formation of West Caicos. This diagram emphasizes the role of primary north-south trending spine ridges controlling east-west trending sediment deposition. Most notably, figures D and E display longshore leeward coast transport of subtidal ooid grainstones sourced from both north and south.

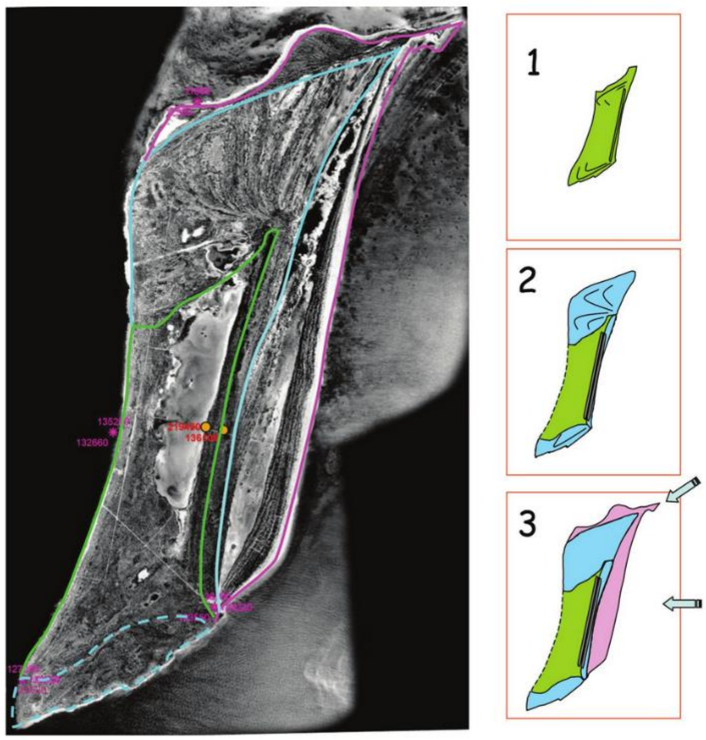


Figure 4. Diagram from Simo et al. (2008) showing similar proposition for the formation of West Caicos. This diagram is constrained with several age dates, and places similar emphasis on an older core with a radially spreading younging direction.

Increased precision from advancements in U/Th dating techniques and the addition of amino acid racemization dating shows there are resolvable sea level fluctuations, or substages, within the MIS 5e (Carboni et al. 2014; Hearty 2002; Hearty et al. 2007; Johnson 1991; Lecca and Carboni 2007; Neumann and Hearty 1996) (Fig. 5).

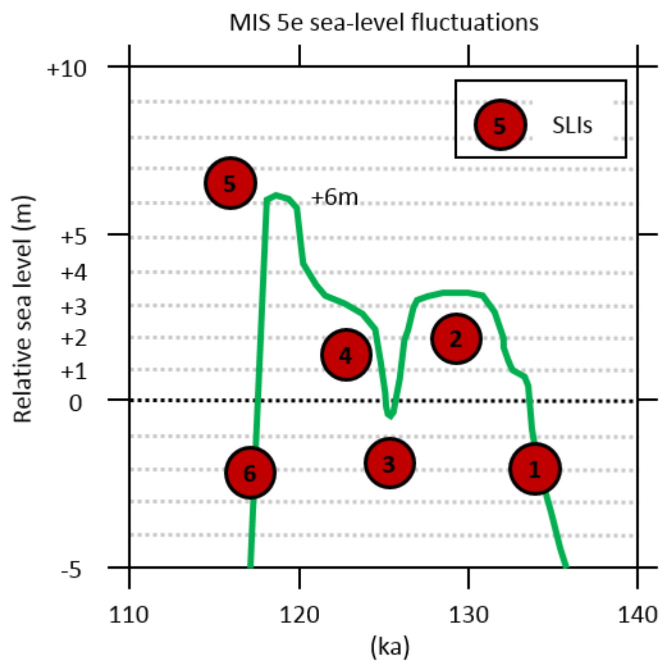


Figure 5. Graph modified from Hearty et al. (2007) showing resolvable sea level fluctuations within the MIS 5e. The entirety of MIS 5e is constrained by points 1 and 6 on this graph. Point 2 indicates a rise up to +3 m in sea level (MIS 5e_1) before sea level drops slightly below present day level (point 3). Points 4 and 5 mark a rapid rise in sea level from near present day to +6 m (MIS 5e_2). This rapid rise is only sustained for 2-4 ky before dropping back below present sea level around 118 kya (point 6).

This principle of a multiple stage MIS 5e has been applied to the geology of West Caicos; Kerans et al. (2015) shows a fringing reef unit 4 meters above sea level reflecting an older MIS 5e_1 unit, and a strandplain grainstone unit that accumulated 4-6 meters above sea level, reflecting a younger MIS 5e_2 unit—these two units are separated by an erosional unconformity.

FACIES

Six facies were identified within the strandplain grainstone unit (Table 1). The facies were identified using diagnostic sedimentary structures, grain size, grain type, cement type, geometric distribution, and ichnofacies. Each facies unit represents a depositional environment with a particular energy and water depth association. Facies names in this paper derive from Dunham's classification of carbonate rocks (Dunham 1962). Understanding facies relationships provides insight into the depositional setting, 2D and 3D sequence stratigraphic framework, and the overall architecture of this strandplain grainstone. Facies recognized in this study include: (A) laminar to brecciated caliche cap, (B) shallow, swash-laminated seaward-dipping ooid grainstone, (C) high-angle, coarse skeletal-intraclastic grainstone , (D) trough-cross-stratified ooid grainstone, (E) moderately bioturbated trough-cross-stratified ooid grainstone, and (F) massive, bioturbated ooid grain-dominated packstone.

Facies Reference	Facies Name	Dunham Classification	Dominant Grain Types (In order from most to least abundant)	Sedimentary Structures	Environment of Deposition Interpretation
A	Heavily karsted caliche cap	N/A	N/A	N/A	Paleosol formed during prolonged events of platform exposure
B	Shallow laminar seaward dipping ooid grainstone	Lithoclast-peloid-ooid grainstone	Ooids, peloids, lithoclasts, molluscs	Parting lineations, keystone vugs, shallow laminar beds	High energy swash zone, foreshore
C	Thin bed of coarse skeletal grainstone	Ooid-peloid-mollusc-lithoclast grainstone	Lithoclasts, molluscs, peloids, ooids, grapestones	Minor trough-cross-stratification	Very high energy swash zone, plunge zone between foreshore and upper shoreface
D	Trough-cross-stratified ooid grainstone	Lithoclast-peloid-ooid grainstone	Ooids, peloids, lithoclasts, molluscs	Trough-cross-stratifaction	High energy shallow subtidal, upper shoreface
E	Bioturbated trough-cross-stratified ooid grainstone	Lithoclast-peloid-ooid grainstone	Ooids, peloids, lithoclasts, molluscs	Minor trough-cross stratification, bioturbation	Moderate energy subtidal, lower upper shoreface
F	Massive bioturbated ooid grainstone	Peloid-ooid grainstone	Ooids, peloids	Massive, bioturbation	Low-moderate energy subtidal, lower shoreface

Table 1. The 6 dominant facies types within the strandplain grainstone. Pertinent information includes Dunham classification, dominant grain types, sedimentary structures, and interpretation of environment of deposition.

A. BRECCIATED GRAVEL IN RED-ORANGE MATRIX

Facies A features red-orange iron oxides with large, brecciated cm-scale gravel incorporated into the matrix (Fig. 6). This facies caps facies B, and are interpreted as a caliche, or paleosol cap; this paleosol formed during a period of platform exposure after MIS 5e_2.

Figure 6. Heavily karsted caliche cap. Caliches accumulate during periods of non-carbonate deposition, and are subsequently reliable indicators of platform exposure. This caliche caps the strandplain sequence, and marks a period of platform exposure after the MIS 5e_2.

B. SHALLOW, SWASH-LAMINATED SEAWARD-DIPPING OOID GRAINSTONE

Facies B features millimeter-to-centimeter shallow laminated strata dipping 4-8° seaward (average 5°). The dominant allochems are ooids (54%), peloids (33%), and intraclasts (8%). Meniscus blocky calcite cement indicates vadose diagenesis; cement is concentrated near grain contacts, where capillary pore water would be held and precipitate meniscus cement (Scholle and Ulmer-Scholle 2003). Due to the presence of shallow, swash-laminated seaward dipping beds, parting lineations, and keystone vugs, this facies is interpreted as a foreshore environment (Fig. 7).

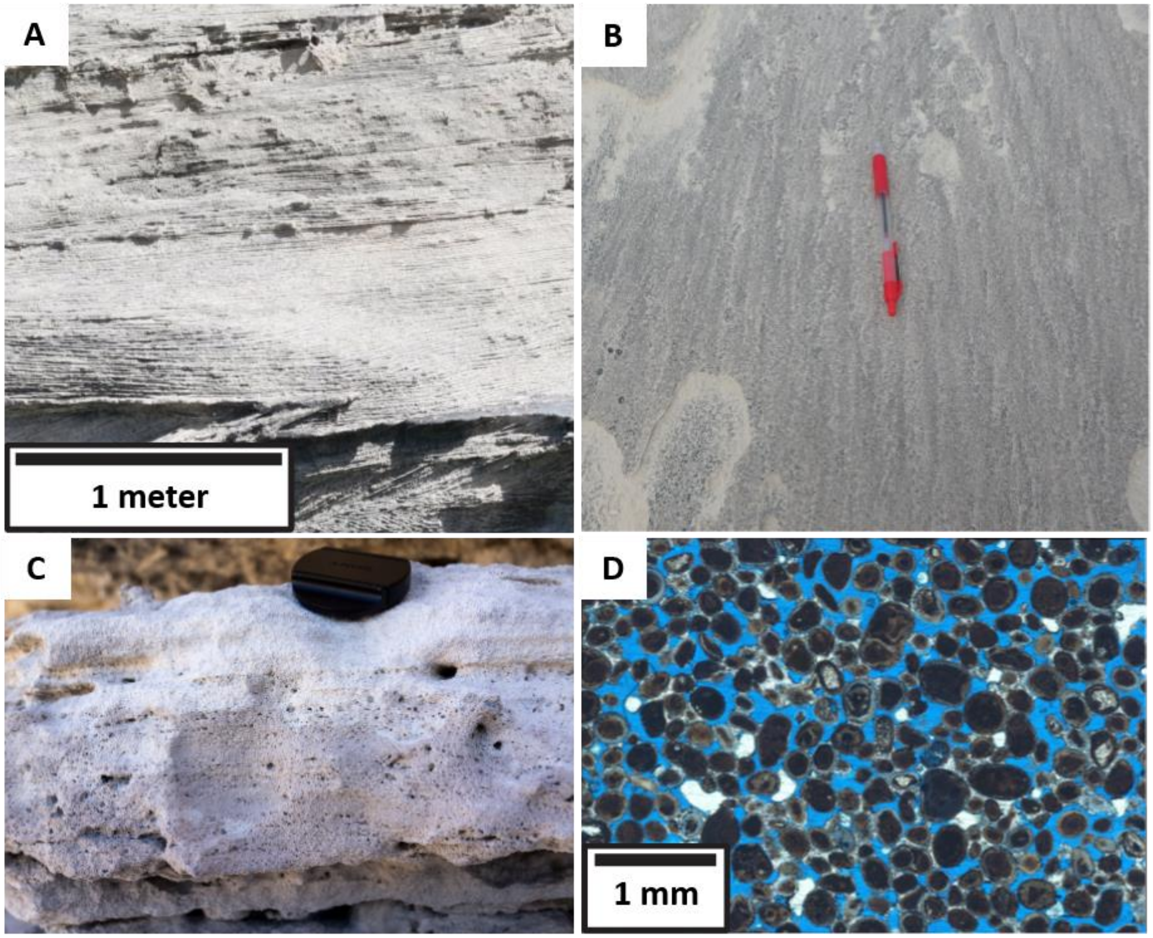


Figure 7. Diagnostic sedimentary structures and a representative thin section image for the foreshore. 7A) Shallow, seaward dipping laminar beds. 7B) Parting lineations in plan view. 7C) Fenestrae or keystone vugs. 7D) Petrographic image of the foreshore. Note the dominantly oolitic nature.

C. High-angle, coarse, composite grained rudstone

Facies C is markedly coarser than surrounding facies and is primarily composed of skeletal material and aggregate grains such as intraclasts and grapestones (Fig. 8). This unit is generally less than 0.5 m thick, and laminations dip between 15-20° seaward. Due to its steeply dipping nature and coarse rudstone fabric, this facies is interpreted as the plunge zone or the plunge step (Clifton et al. 1971; Rowe et al. 2014). The plunge zone forms where waves break, typically in five to fifteen centimeters of water depth, making it the highest energy domain on the beach (Dabrio et al. 2011; Zazo et al. 2003).

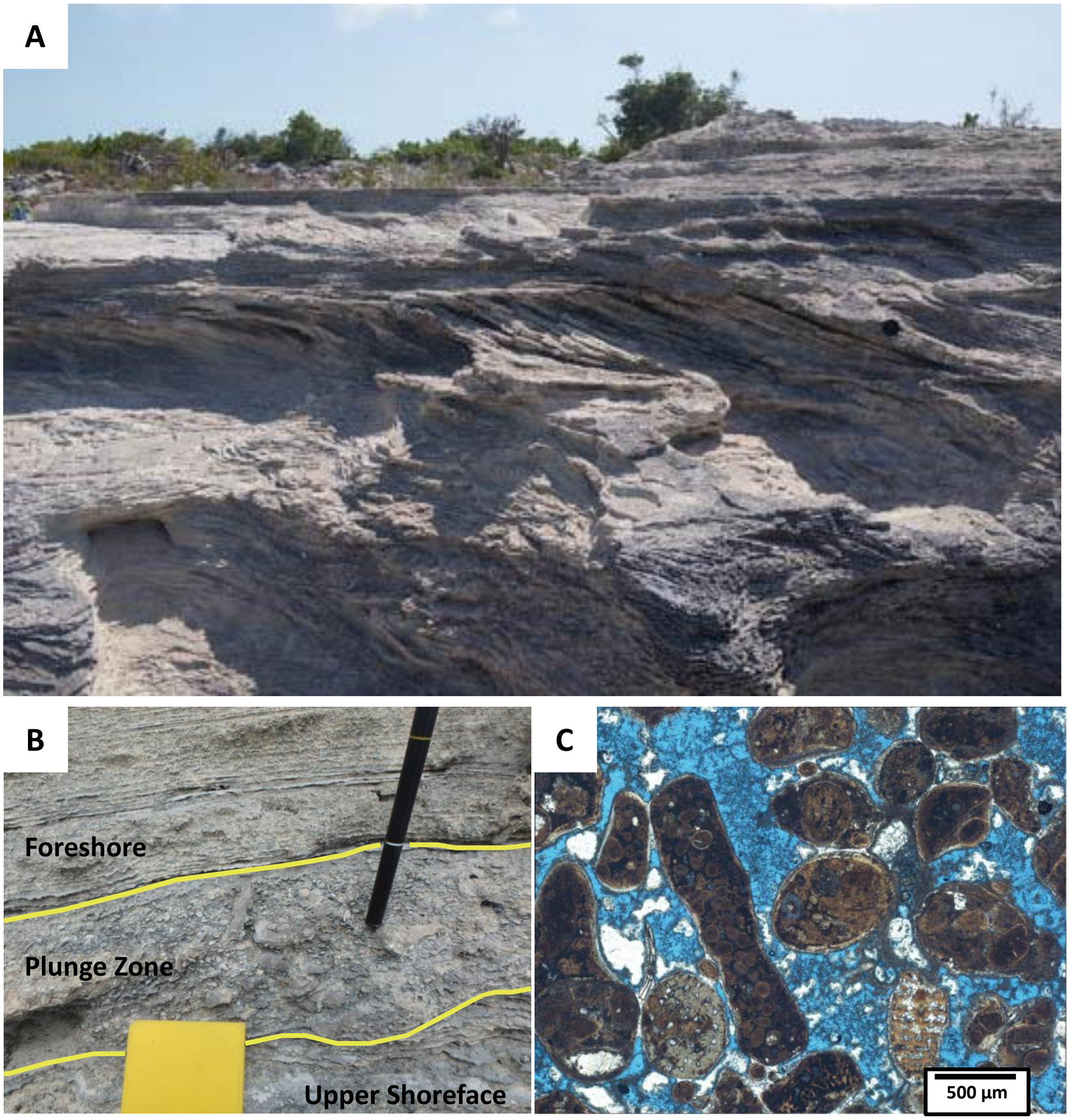


Figure 8. Grain sizes and spatial relationships typically associated with the plunge zone. 8A) Field photo showing steeply dipping nature of the plunge zone. 8B) Spatial relationship of the plunge zone, with laminar foreshore beds above and upper shoreface trough cross beds below. 8C) Petrographic image of the plunge zone; note the coarse nature of the grains, with most grains between 500 µm and 1 mm.

D. Trough-cross-stratified ooid grainstone

Facies D features intraclast-peloid-ooid grainstones with common trough-cross-stratification (Fig 9). Dominant allochems include ooids, peloids, intraclasts, bivalves, and gastropods. Similarly to the foreshore, these grains are weakly lithified by a meniscus calcite cement indicating vadose diagenesis. This facies is marked by southward trending trough-cross-beds, which were used for paleoflow analysis. Bedset size for the trough-cross-strata ranged from 5-20 cm in thickness. This facies is interpreted as a moderate-high energy upper shoreface environment due to the presence of trough-cross-stratification, shore-parallel paleocurrents, and its spatial distribution seaward of the foreshore. This style of longshore trough-cross-stratification has been observed in coastal deposits on New Providence (Garrett and Gould 1984; Hearty and Kindler 1997), San Salvador (Hearty and Kindler 1993; Mylroie and Carew 2008), Eleuthera (Hearty 1998), and numerous other Pleistocene carbonate islands.

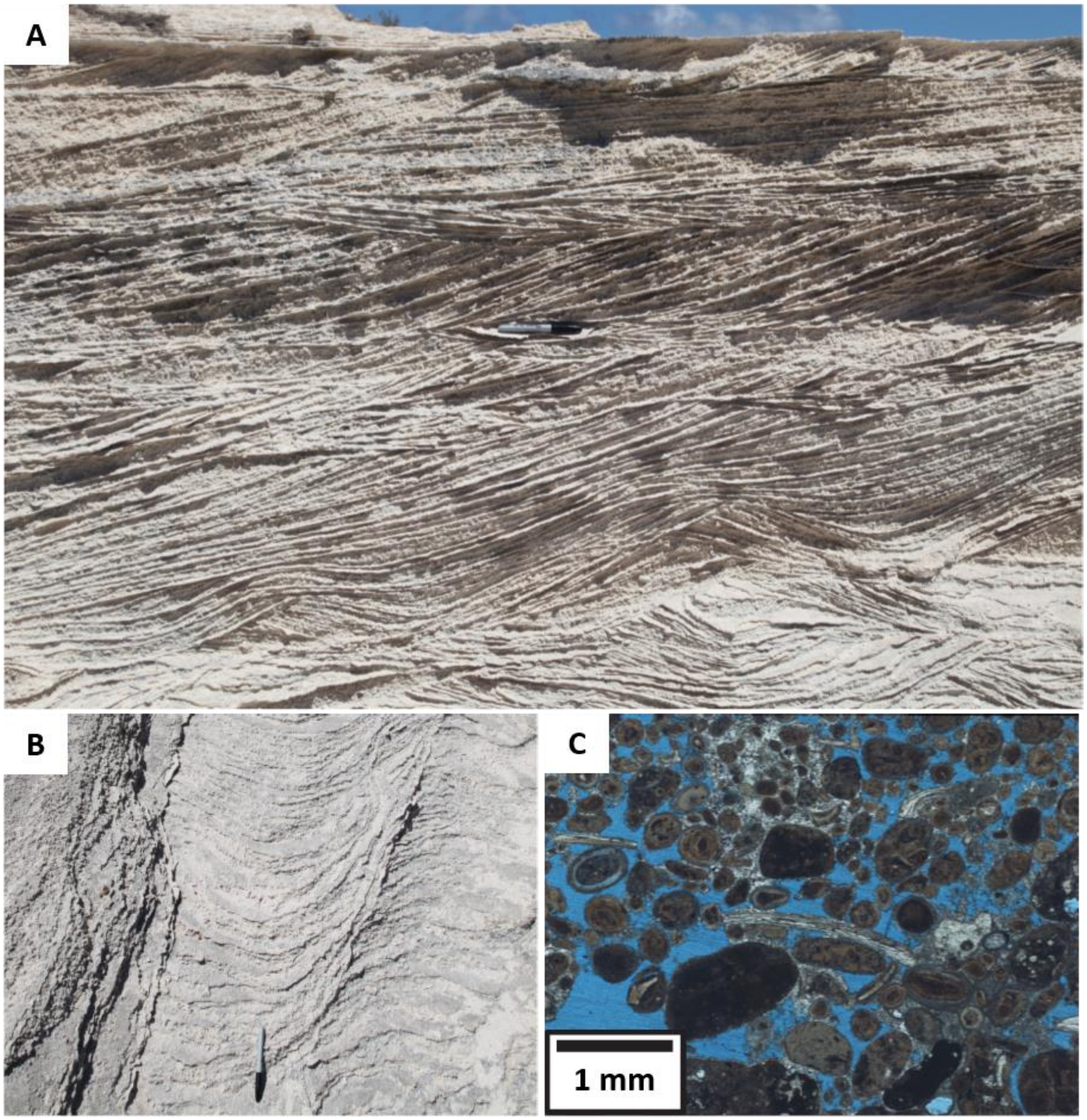


Figure 9. Diagnostic sedimentary structures associated with the upper shoreface. 9A) Trough-cross-strata in cross section. 9B) Trough-cross-strata in plan view. Measuring the axis of the upper shoreface troughs alludes to paleoflow direction. 9C) Petrographic image of the upper shoreface. Note the dominant grains: ooids, bivalve fragments, peloids, and lithoclasts.

E. Bioturbated trough-cross-stratified ooid grainstone

Facies E features trough-cross-beds which are cross-cut by common *Ophiomorpha* and rare *Diplocraterion* burrows. This facies is interpreted as a transition zone between the trough-cross-stratified shallow subtidal (upper shoreface), and the massively bioturbated, stabilized subtidal (Fig. 10).

Figure 10. Facies image of the bioturbated trough-cross-stratified ooid grainstone. Although trough-cross-strata are still present, there is moderate bioturbation affecting the preservation of sedimentary beds. This unit is a transition zone from the trough-cross-stratified shallow subtidal, and the massively bioturbated stabilized subtidal.

F. Massive bioturbated ooid grain-dominated packstone

Facies F features massively bioturbated ooid grain-dominated packstones with abundant *Ophiomorpha* and *Planolites* burrows, and rare *Diplocraterion* burrows (Fig. 11). The absence of sedimentary structures such as trough-cross-strata and presence of bioturbation suggests this facies is a lower energy, stabilized section of the subtidal (Wanless and Dravis 1989).

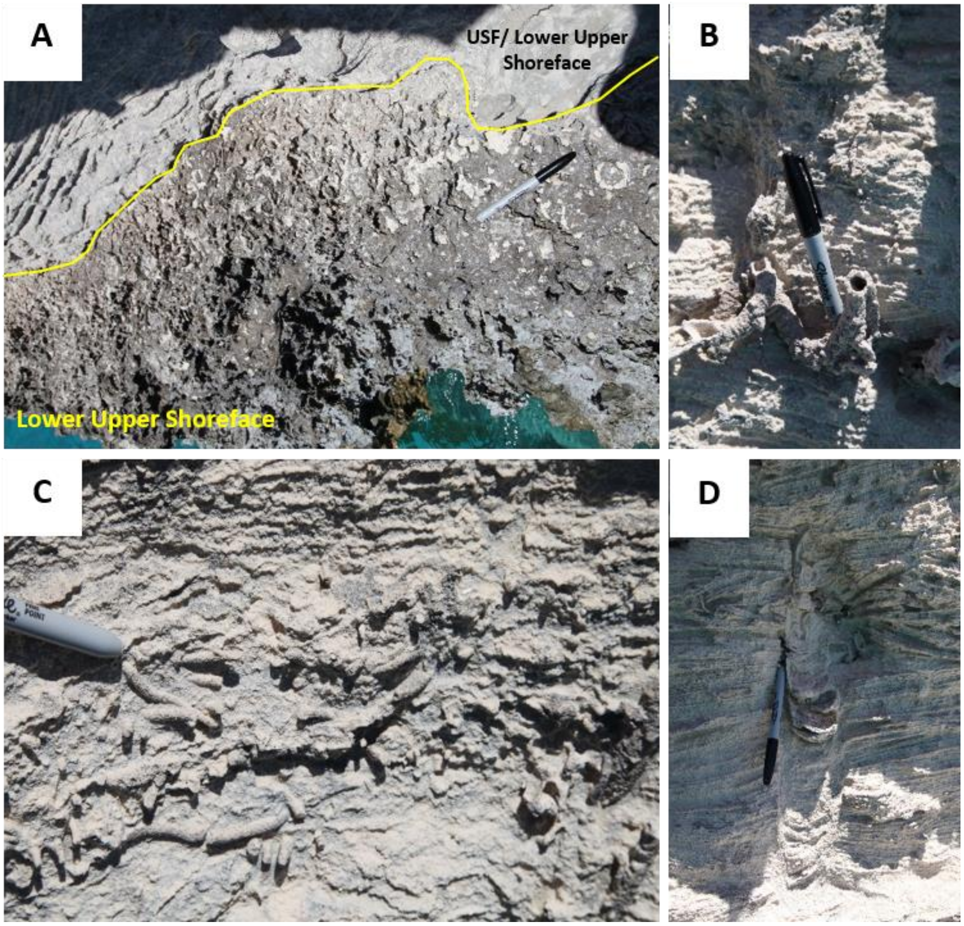


Figure 11. Different ichnofacies and facies photographs from the lower upper shoreface. 11A) Facies photograph displaying the relationship between the lower upper shoreface and the bioturbated trough-cross-stratified grainstones. Note the true lower upper shoreface does not have any bedding and has a distinct mottled fabric, while the "USF/lower upper shoreface" layer still has preservation of trough-cross-strata. 11B) Ophiomorpha burrows. 11C) Planolites burrows. 11D) Diplocraterion burrow.

METHODS

Mapping

Several wave eroded notches along the west coastline provide opportune locations for cross sections through grainstone bodies and allow for close examination of facies variability within the strandplain from north to south. Three cross sections were taken along the coastline to demonstrate facies relationships and variability, strandplain thicknesses, and to allow close examination of sedimentary structures and ichnofacies. The cross sections were created with thirteen measured sections and 3 high-resolution photomosaics. Field observations and the photomosaics were used in conjunction to correlate facies

Figure 12. Overhead Google Earth image of West Caicos with locations of diagnostic 2D cross sections, overhead maps, and 3D depositional models.

between measured sections. Photomosaics also document facies bedding relationships, along-dip facies variability, and, in this case, sedimentary structures. Two of these cross sections, in addition to field measurements and photos, were used to create 3D depositional models which demonstrate the evolution of the strandplain unit from north (Boat Cove) to south (Yankee Town) (Fig. 12).

PETROGRAPHIC SAMPLING

For petrographic analysis, 75 samples were collected from 13 transects along the west coast at half-kilometer intervals (Fig. 13).

Figure 13. Overhead Google Earth image of West Caicos with sampling locations of 13 petrographic transects, with an average of 4 thin sections made per transect Sampling was focused on foreshore and upper shoreface grainstones, but lower upper shoreface grainstones were sampled when present along the profile.

From the selected samples, 53 thin sections made from selected samples were analyzed for grain size and grain type. For grain size analysis, 200 grains per thin section were measured using Nikon's NIS-elements software, for a total of 10,400 grains. For grain type, 200 grains per thin section were randomly selected from the photomosaic imagery using the point counting software JMicroVision, and identified from a list of common carbonate grains on the Caicos platform (ooids, peloids, bivalves and gastropods, coral fragments, *Peneroplis*, *Halimeda*, *Goniolithon*, and intraclasts). Grain size and grain type were analyzed by facies along a north to south trend along the strandplain. Additionally, samples were taken from actively forming ooid factories at Ambergris Cay and Long Road Beach (eastern side of West Caicos) for grain type comparison to the leeward West Caicos strandplain.

PALEOCURRENT MEASUREMENTS

Paleocurrent measurements were taken from upper shoreface trough-cross-strata along the northern half of the coastline in order to demonstrate the persistently southward-directed paleoflow and to allude to provenance of these strandplain grainstones (Fig. 14). Approximately 20 measurements were taken from 9 upper shoreface locations along the coastline, totaling 182 total paleocurrent measurements. Obtaining paleocurrents along the southern half of the west coast proved difficult because the upper shoreface becomes increasingly patchy in its distribution and is eventually absent from the facies profile.

Figure 14. Upper shoreface troughs in plan view; the dominant flow or growth direction for the strandplain can be ascertained by measuring the axis of the troughs where available along the upper shoreface profile.

VOLUMETRIC ANALYSIS

3D airborne LIDAR of West Caicos was supplied by the Reservoir Characterization Research Laboratory at the Bureau of Economic Geology. The LIDAR dataset was exported into Petrel, where interpreted facies maps by Kerans et al. (2015) were used to determine the lateral stratigraphic extent of the MIS 5e_2 grainstones. A geobody was created by constraining the grainstones in three dimensions; the LIDAR points constrained the upward extent, the stratigraphic interpretation constrained the lateral extent, and a surface created at sea level constrained the downward spatial extent (Fig. 15). Volume of the MIS 5e_2 grainstone geobody was obtained using the calculate volume function in Petrel. Accumulation rates for the grainstones were acquired using known constraints on timing of deposition and volume of sediment; rates were measured by volume deposited per thousand years (m^3/ky) and by overall one dimensional vertical accumulation (m/ky).

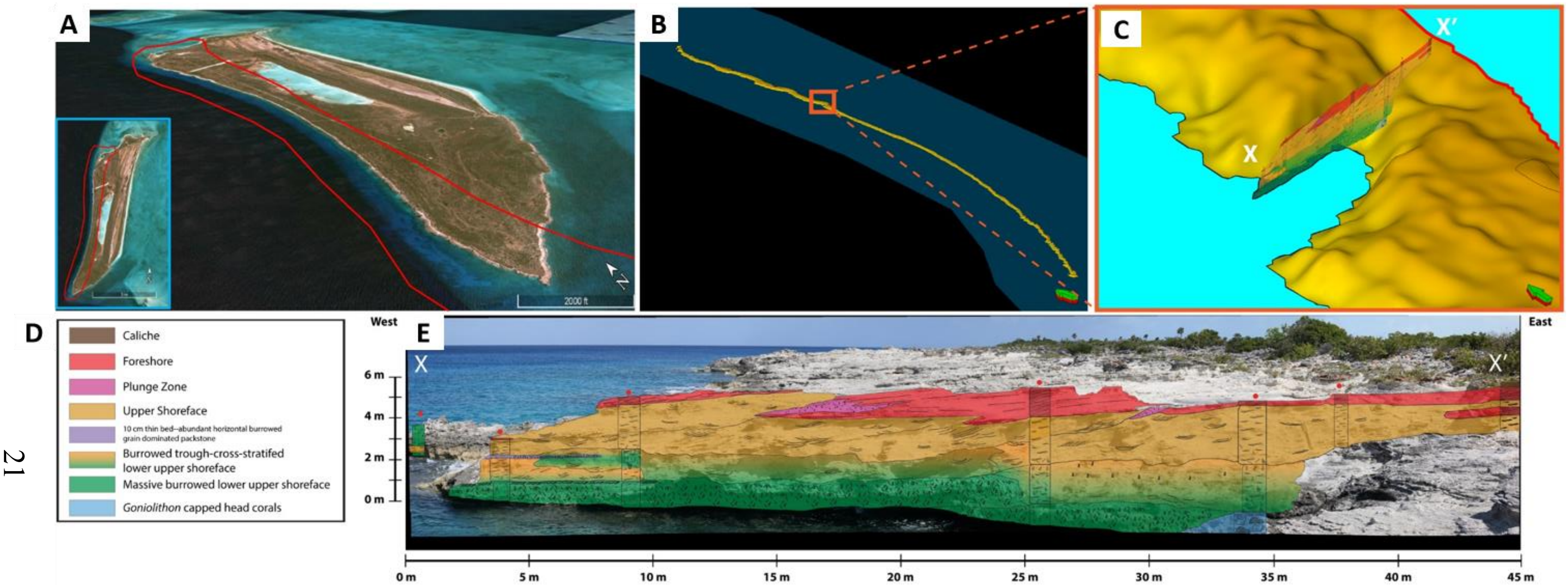


Figure 15. 15A) An overhead and oblique view of West Caicos, showing the geographic extent of the Lidar data used for this study (red outlined polygon). 15B) An oblique view of the Lidar dataset. The transparent blue polygon represents modern sea level, and controls the downward spatial extent of the geobody, as geologic mapping cannot be conducted below sea level. The elongate yellow geobody is the depositional extent of the MIS 5e along the leeward coast of West Caicos. As this geobody contains both grainstone facies from MIS 5e_2 and reef facies from MIS 5e_1, facies maps from Kerans, in progress, were used in volumetric calculations to obtain the correct proportion of 5e_2 grainstones. 15C) A closeup oblique view of the Lidar dataset at Boat Cove. The light blue represents sea level, and is the downward extent of the geobody. The yellow polygon represents the Lidar dataset, and the red line on the X’ side of the geobody represents the lateral stratigraphic extent of the MIS 5e_2 deposits. Note the geologic cross section of Boat Cove has been draped over the Lidar dataset for reference 15D) Facies legend. 15E) Unaltered interpreted photopan of Boat Cove.

RESULTS

MEASURED SECTIONS, CROSS SECTIONS, AND 3D DEPOSITIONAL MODELS

Tidal Inlet

This mapped area includes the typical foreshore-plunge zone-upper shoreface succession, but also contains planar, steep foresets dipping in both seaward and landward directions. An interpreted photomosaic and a geologic map of this area were created to understand the distribution of these steeply dipping foresets (Fig. 16). The vertical facies succession (starting with the most distal facies) includes massive bioturbated lower upper shoreface grain-dominated packstones, trough-cross-stratified upper shoreface grainstones which are interrupted by a meter thick unit of steep foresets dipping 23° in a landward direction of 138-148°; these landward-dipping foresets have bedsets between 5-20 cm thick. Deposited on top of these steep landward-dipping foresets is a 1.5 m thick unit of steep seaward-dipping foresets; these foresets dip at 25° in a seaward direction of 255-260°. Above these steep, seaward dipping foresets, the typical strandplain facies assemblage continues with more trough-cross-stratified upper shoreface grainstones and finally laminar, gently dipping foreshore beds.

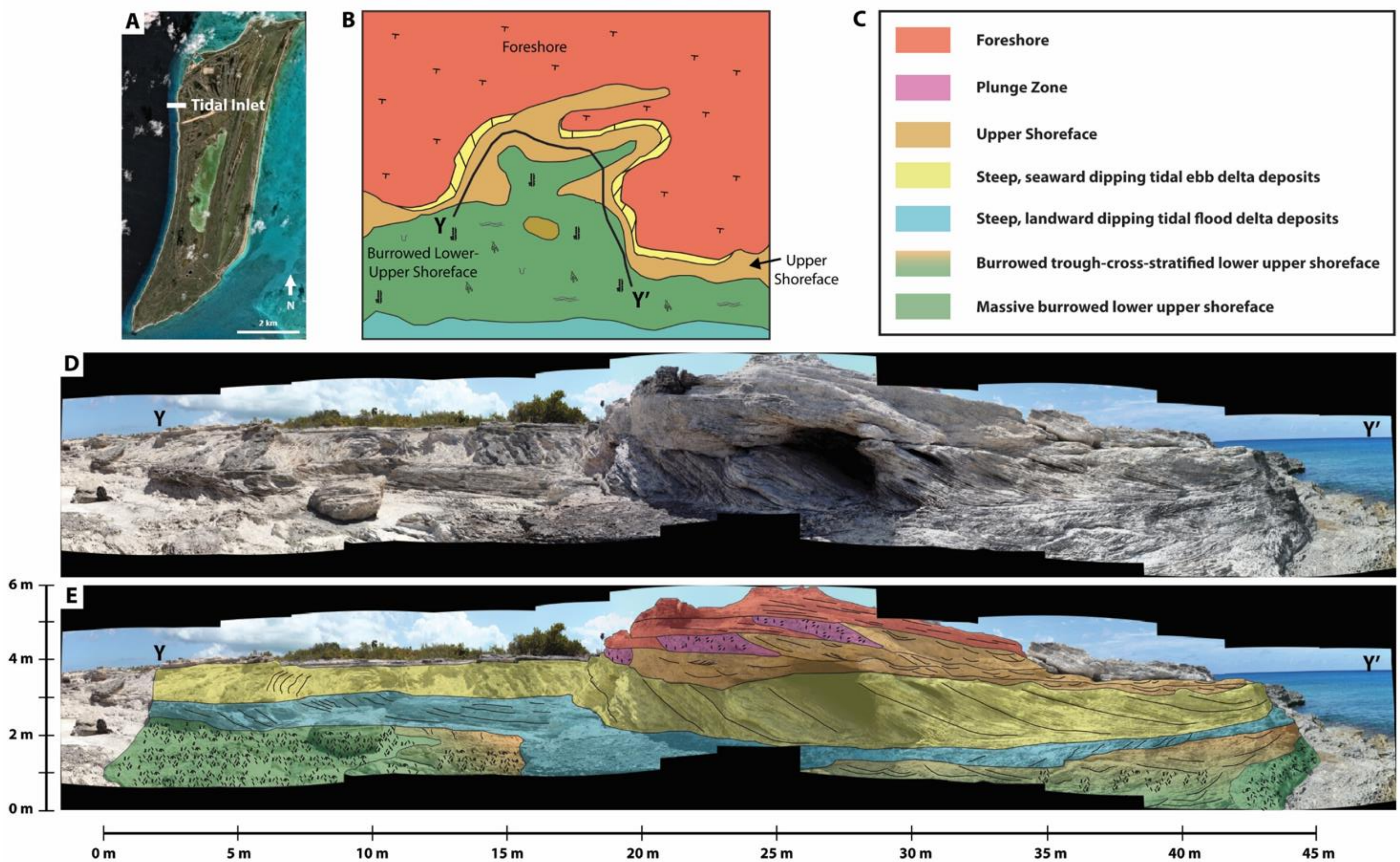


Figure 16. 16A) Overhead Google Earth image of West Caicos showing the location of the Tidal Inlet section. 16B) Overhead geologic map of the tidal inlet showing the distribution of foreshore-upper shoreface deposits in relation to the steeply dipping foreset deposits. Note the distribution of the foreset deposits is better displayed in cross section. 16C) Facies legend. 16D) Uninterpreted photopan of the Tidal Inlet section. Note there is slight distortion in this image, as the section was projected in a 2D cross section but the Tidal Inlet is fairly three-dimensional. 16E) Interpreted cross section of the Tidal Inlet section. Note the typical upper shoreface-foreshore strandplain succession is interrupted by steeply dipping foreset deposits, dipping in both a landward direction and seaward direction.

Boat Cove

Boat Cove is a wave eroded notch which provides a cross sectional view through the thickest part of the 5e_2 strandplain, and displays the dominant facies relationships within the strandplain system. Sedimentary structures and ichnofacies within these grainstone units are exceptionally well preserved, aiding in the identification of facies. Facies distributions in Boat Cove were analyzed in one dimension using measured sections, two dimensions by creating an interpreted cross section and overhead map (Fig. 17), and three dimensions through the creation of a comprehensive depositional model (Fig. 18). Grainstone assemblages are upwards of five meters thick with dip-widths between thirty and forty meters. Lateral facies continuity is exceptional in comparison to further south (Yankee Town), with some foreshore and upper shoreface facies tracts traceable for several 100's of meters along strike (north-south). Foreshore beds at Boat Cove dip at an average of 5° in a direction slightly north of west (282°). Upper shoreface troughs in the immediate vicinity of Boat Cove show a southward paleoflow direction, with an average of 195.3°. Grainstones are deposited locally on corals from MIS 5e_1, which rest a half-meter above sea level. Moving from north to south, Boat Cove is one of the first locations along the coastline where MIS 5e_1 deposits become visible.

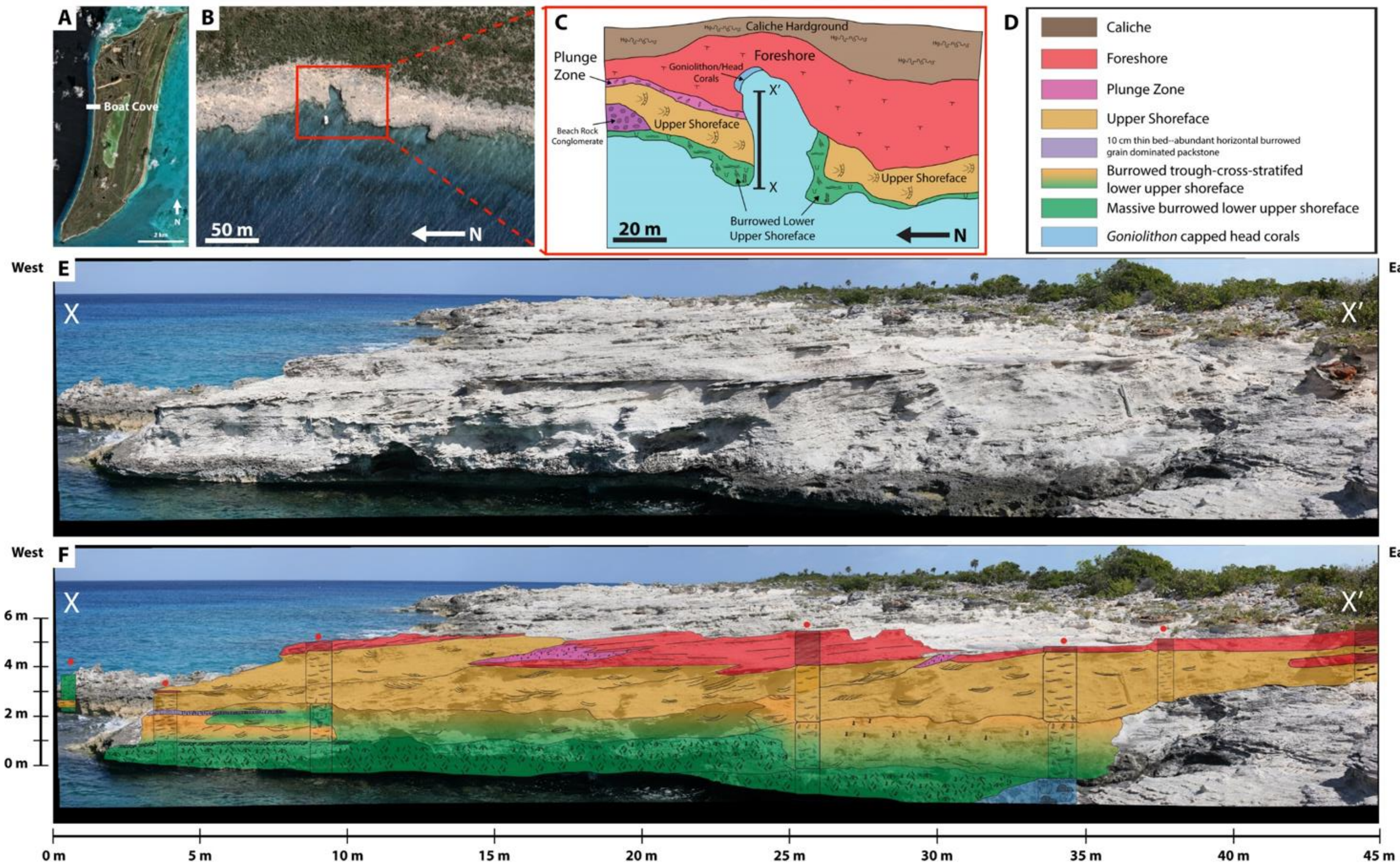
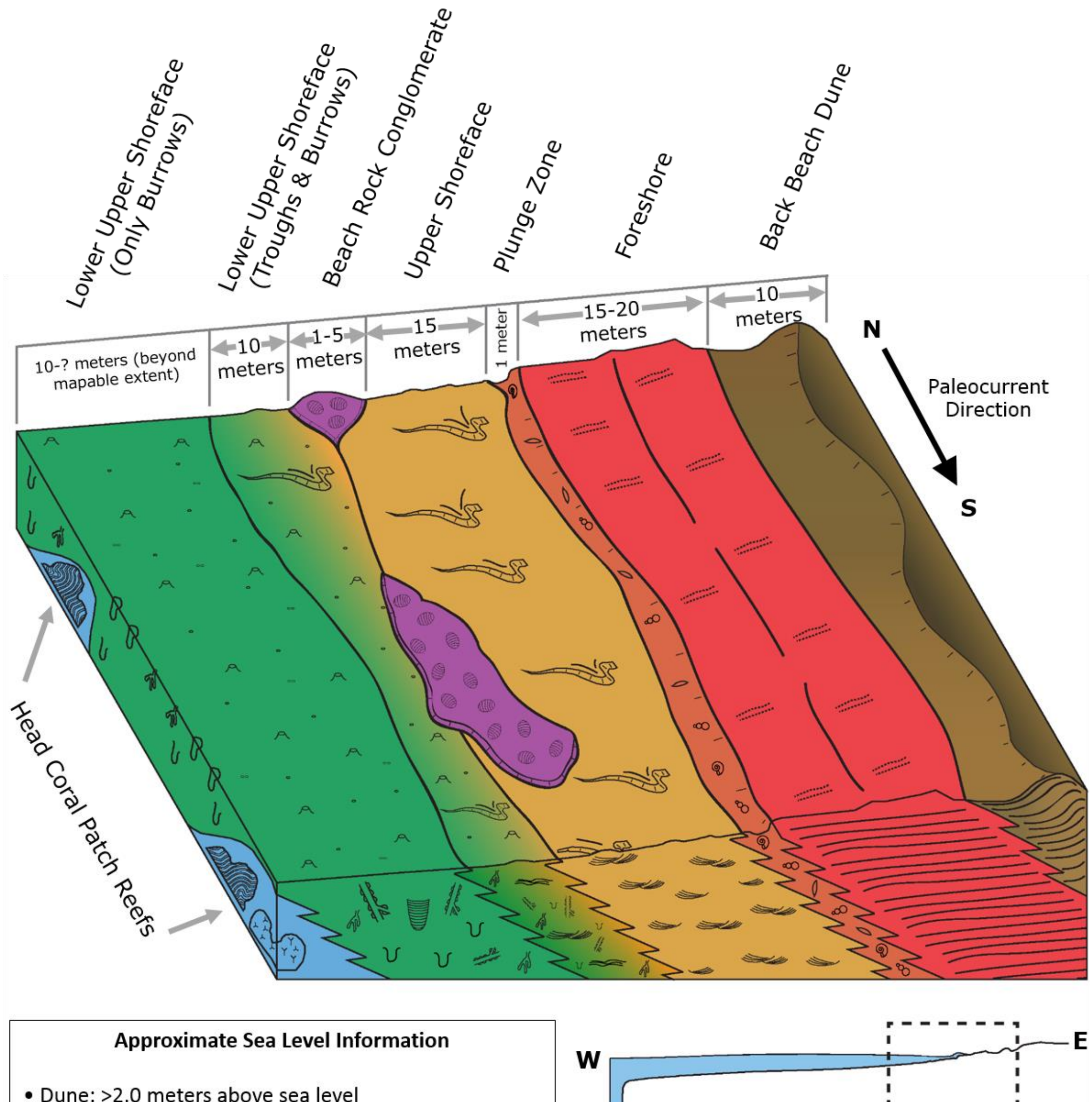


Figure 17. 17A) Overhead Google Earth image of West Caicos showing the location of Boat Cove. 17B) Boat Cove in plan view (Google Earth Image). 17C) Overhead geologic map of Boat Cove showing the foreshore-plunge zone-upper shoreface facies relationships. Note the location of the cross section, marked X-X'. 17D) Facies legend. 17E) Uninterpreted dip-oriented photopan of the north-side wall of Boat Cove. 17F) Interpreted dip-oriented photopan of Boat Cove showing dip parallel facies relationships. Dip widths are on the order of tens-of-meters, strandplain thickness is between 4-6 m, and the strandplain body is as much as +6 m above present day sea level.



Approximate Sea Level Information
• Dune: >2.0 meters above sea level
• Foreshore: 0.0-2.0 meters above sea level
• Plunge Zone: 0.0-0.5 meters below sea level
• Upper Shoreface: 0.5-2.5 meters below sea level
• Lower Upper Shoreface: >2.5 meters below sea level

Figure 18. A 3D depositional model of Boat Cove; this serves as a representative facies succession for the northwest coast, where the foreshore- upper shorface strandplain grainstones are dominant. Note the along strike (north-south) continuity of the facies units. The shallowing upward facies succession includes massive bioturbated upper shoreface grain-dominated packstones, bioturbated and trough-cross-stratified grainstones, trough-cross-stratified upper shoreface grainstones, coarse grained steeply dipping plunge zone, and shallow seaward-dipping laminar bedded foreshore grainstones. During high energy storm events, early cemented beach-rock from the foreshore is ripped up and deposited as decimeter-meter scale blocks in the shallow subtidal (typically in the upper shoreface). These ripped up beach rocks relithify together in the subtidal as beach rock conglomerate.

Yankee Town

Yankee Town is along the strandplain further south than Boat Cove, where the grainstone distribution is sparse, and reefal facies dominate. The along-strike continuity of grainstone units decreases greatly from north to south as reefal facies become dominant. Yankee Town provides a rare cross sectional view through dominant reef facies of the southwestern leeward margin (Fig. 19). Similarly to Boat Cove, a 3D depositional model of Yankee Town was created from one-dimensional measured sections and a 2D overhead map and interpreted cross section (Fig. 20). Foreshore-upper shoreface grainstone assemblages are 1-2 meters thick and have dip-widths between 5-10 meters. Lateral facies continuity is significantly less in Yankee Town than at Boat Cove; at maximum, foreshore and upper shoreface facies tracts are traceable for a few tens-of-meters along strike.

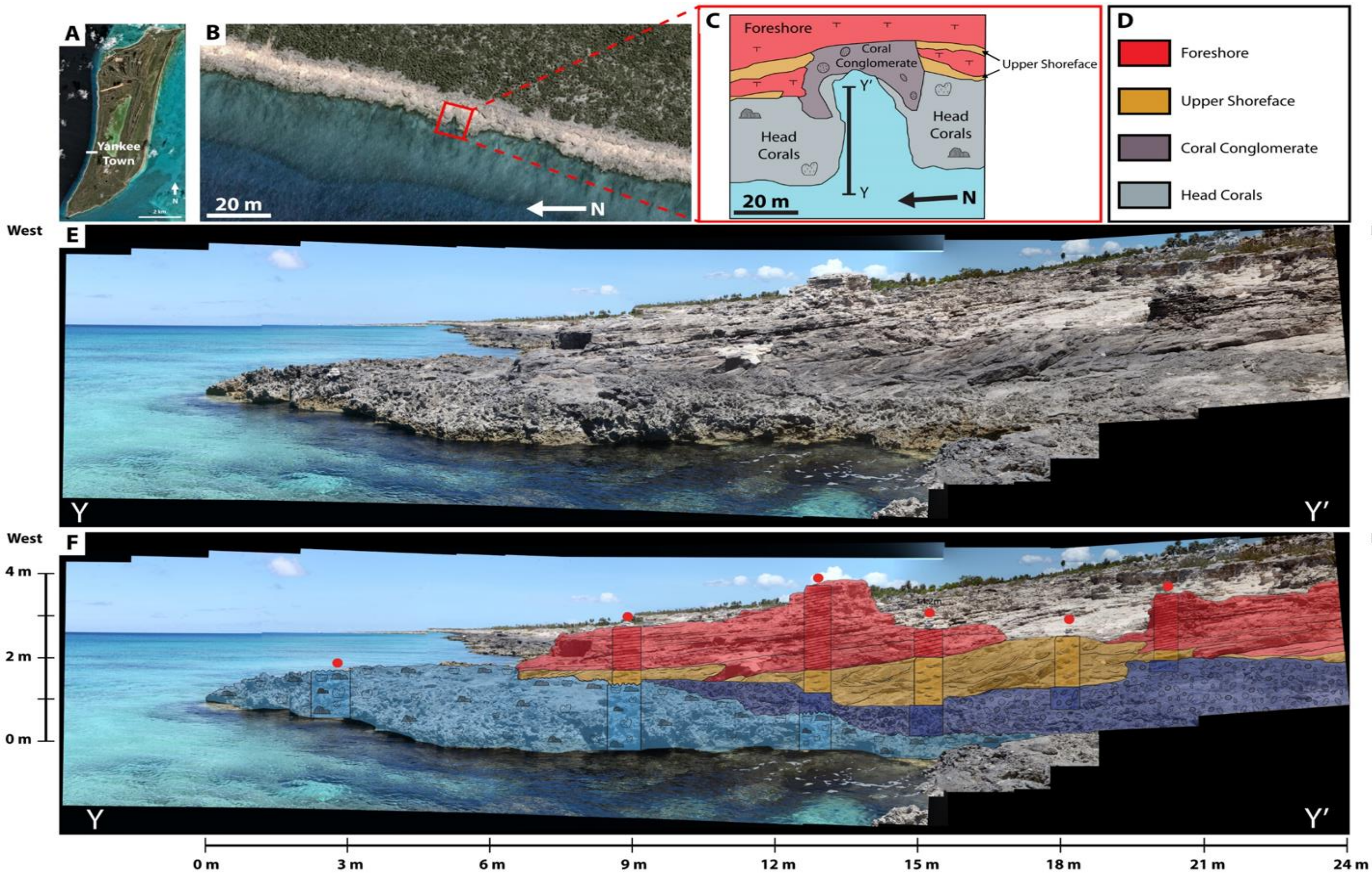
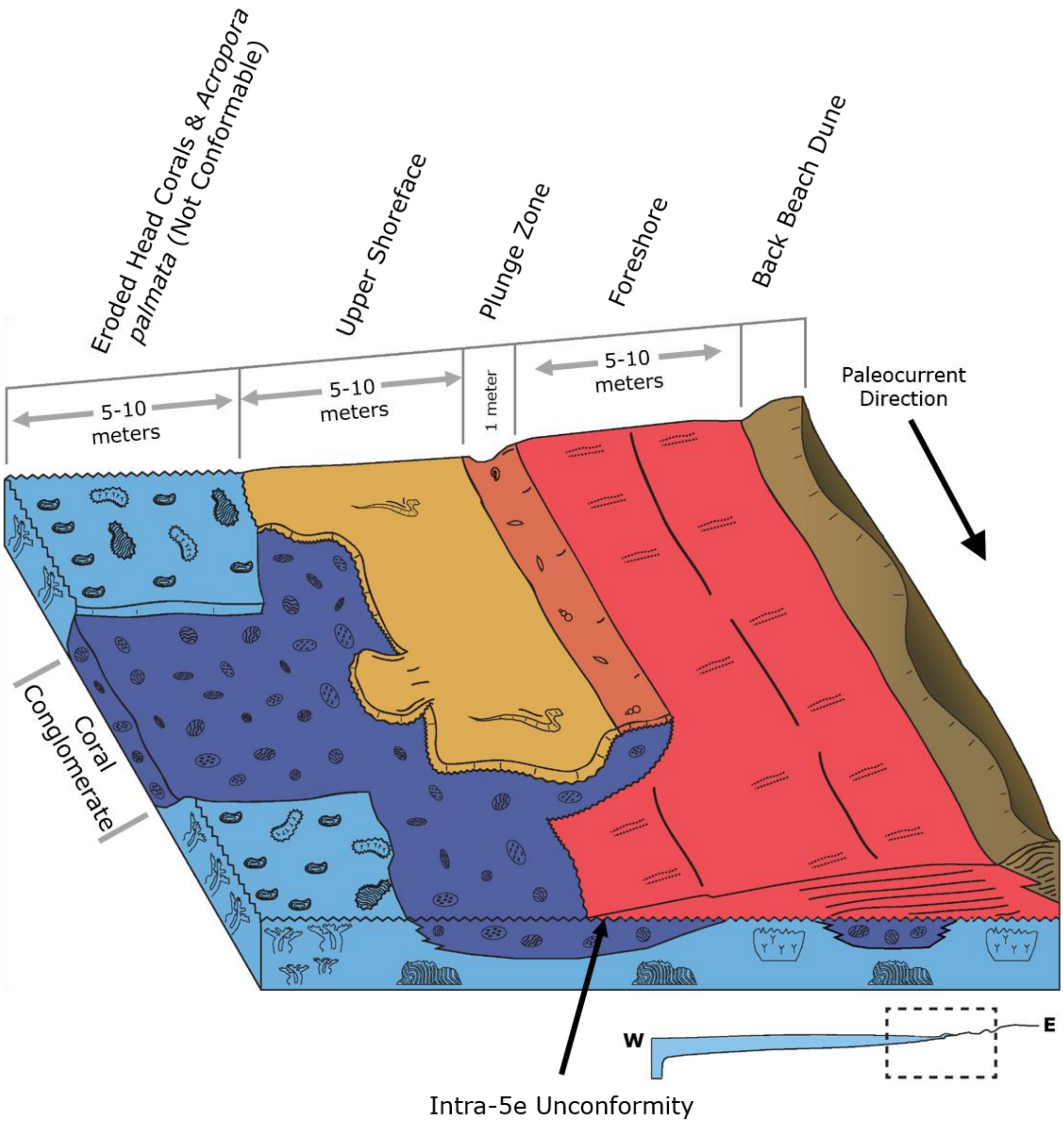


Figure 19. 19A) Overhead Google Earth image of West Caicos showing the location of Yankee Town. 19B) Yankee Town Inlet in plan view. 19C) Overhead geologic map of Yankee Town showing distribution of strandplain grainstone facies (foreshore and upper shoreface) in relation to earlier reefal deposits (coral conglomerate and head corals such as Diploria and Montastraea. 19D) Facies legend. 19E) Uninterpreted dip-oriented photopan of the north-side wall of Yankee Town Inlet. 19F) Interpreted dip-oriented photopan of Yankee Town Inlet showing cross-sectional facies relationships between 5e_2 foreshore-upper shoreface strandplain grainstones of the MIS 5e_2 and underlying reefal facies likely from MIS 5e_1 time. Dip-widths and total strandplain thickness are significantly less here than at Boat Cove; dip widths in this section are between 5-15 m, and the strandplain grainstones have a maximum 2 meter thickness. The strandplain deposits in this cross section are deposited as high as 4 meters above sea level.



Approximate Sea Level Information
• Dune: >2.0 meters above sea level
• Foreshore: 0.0-2.0 meters above sea level
• Plunge Zone (where existing): 0.0-0.5 meters below sea level
• Upper Shoreface (where existing): 0.5-2.5 meters below sea level
• Head Corals & *Acropora palmata*: 0.25-2.0 meters below sea level (at this site)
• Coral Conglomerate: 0.25-2.0 meters below sea level (at this site)

Figure 20. A 3D depositional model of Yankee Town; this serves as a representative facies succession for the southwest coast, where reef facies are dominant and strandplain foreshore-shoreface grainstones are thin and patchy in their distribution. Note the head coral/Acropora palmata reefs and coral conglomerate units are separated from the foreshore-shoreface grainstone unit by an erosional unconformity. The reef facies in this area are interpreted as MIS stage 5e_1 in age, while the downlapping grainstone units are interpreted as MIS stage 5e_2 in age (Kerans et al, in progress). Note the patchy, thin nature of the grainstone units; sediment supply of the strandplain seemingly lessens southward along the coast.

PETROGRAPHY

Extensive analysis of grain size and grain type along the leeward profile was conducted in order to visualize petrographic trends, which may lend insight into the provenance of this strandplain. Table 2 displays the average grain size for each facies along the transects. Note that some grain sizes are blank for some facies along particular transects because they are minimal or non-existant in that area.

	Foreshore (μm)	Plunge Zone (μm)	Upper Shoreface (μm)
Transect 1	229	---	375
Transect 2	251	---	360
Transect 3	278	686	284
Transect 4	319	769	269
Transect 5	251	1356	330
Transect 6	227	542	297
Transect 7	221	396	379
Transect 8	241	504	240
Transect 9	252	668	345
Transect 10	274	---	301
Transect 11	271	---	318
Transect 12	269	---	---
Transect 13	307	---	---
Average	**261**	**703**	**318**

Table 2. Average grain size for the different facies along the N-S transect. Refer to figure 13 for transect locations along the leeward margin. 200 grains were counted and averaged for each thin section. For most facies locations, two thin sections were made and analyzed per transect. No significant trend in grain size is noticeable from north to south. There is a trend in grain size between facies; the plunge zone is the highest energy regime along a beach profile, and subsequently has a significantly higher average grain size. The upper shoreface has a slightly higher average grain size than the foreshore; this is likely due to the slightly increased amount of large skeletal grains in the upper shoreface.

Across the north-south strandplain profile, the grain size distribution is fairly homogenous (Fig. 21). One noticeable grain size trend within the facies stands out; the plunge zone is the highest energy regime along the beach profile, and has a much coarser grain profile than the foreshore and upper shoreface.

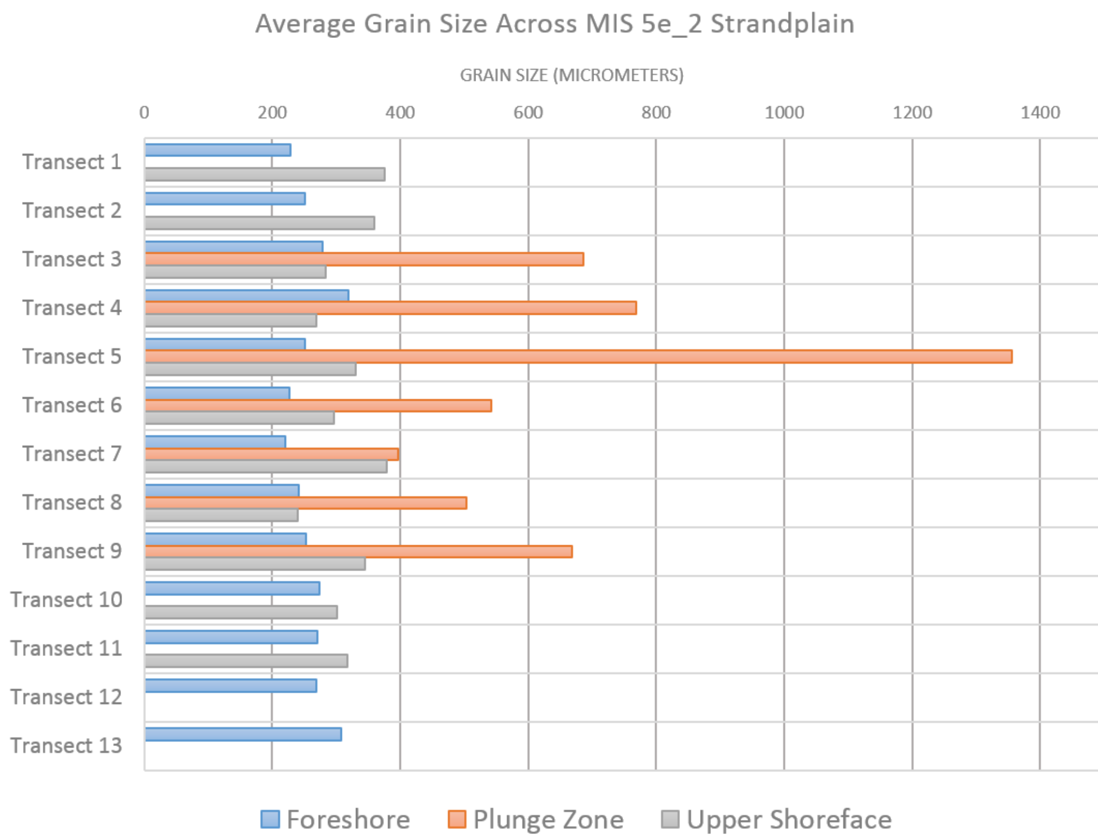


Figure 21. Average grain size for foreshore, plunge zone, and upper shoreface across the transect profile (north-south). Refer to figure 13 for transect sampling locations. There are no significant trends in grain size from north-south; grain size is fairly homogenous across the profile, with the exception of the high-energy coarse-grained plunge zone. The fairly well-sorted nature of the strandplain suggests sediment has undergone a fair amount of transport.

In addition to grain size, grain type analysis was conducted on thin sections from the foreshore and upper shoreface in order to understand the distribution of carbonate grains throughout the strandplain. The overall average petrographic composition of this strandplain is as follows: 54% ooids, 33% peloids, 8% intraclasts, 3% molluscan skeletal material, and 2% other (Table 3). Similarly to grain size, there is not a significant trend from north-south for grain type; the consistent mixing of grains across the strandplain profile also indicates a fair amount of reworking and transport of sediment. Thin sections from Ambergris ooid shoal and the Long Road Beach ooid factory analyzed for grain type are >95% oolitic in composition.

	Ooids (%)	Peloids (%)	Molluscs (%)	Lithoclasts (%)	Other (%)
Transect 1	56	31	3	8	2
Transect 2	47	43	1	8	1
Transect 3	52	33	4	10	1
Transect 4	58	31	3	6	2
Transect 5	76	15	5	3	1
Transect 6	41	35	3	18	3
Transect 7	48	38	4	7	3
Transect 8	56	38	1	4	1
Transect 9	47	34	2	15	2
Transect 10	36	37	3	19	5
Transect 11	61	35	3	0	1
Transect 12	57	32	3	7	1
Transect 13	63	30	1	4	2
Average	**53.7**	**33.2**	**2.8**	**8.4**	**1.9**

Table 3. Grain type along the north-south profile of the strandplain. Grain types were obtained from point counting thin sections from foreshore and upper shoreface facies. 200 grains per thin section and 7800 grains overall were identified in order to understand the petrographic composition of the strandplain. The "other" section of this table consists of carbonate grains which were less common, such as coral fragments, *Peneroplid* foraminifera, *Halimeda*, and *Goniolithon*.

Paleocurrents

The average paleoflow direction from 182 paleocurrent measurements is 194.2°, with a range of 162°-225° (excluding the Runway section, which had a bimodal east-west paleoflow direction). 80% of paleocurrent measurements are between 180°-210°, indicating a north to south transport direction of the upper shoreface grainstones. Table 4 displays all of the paleocurrent measurements; figure 22 shows plotted rose diagrams for all of the measurement locations along the coastline, and figure 23 shows the composite rose diagram for all 182 measurements.

Location:	1	2	3	4	5	6	7	8	9
	195°	175°	196°	203°	193°	194°	194°	188°	198°
	185°	191°	211°	193°	202°	191°	203°	204°	194°
	205°	195°	224°	188°	208°	207°	190°	200°	207°
	197°	206°	218°	201°	187°	182°	188°	193°	202°
	206°	190°	206°	194°	195°	179°	189°	197°	191°
	188°	213°	205°	198°	196°	199°	181°	199°	182°
	174°	176°	189°	183°	201°	203°	207°	184°	207°
	187°	178°	190°	188°	189°	189°	198°	173°	195°
	168°	195°	212°	210°	182°	194°	191°	186°	198°
	182°	182°	203°	217°	193°	192°	211°	179°	191°
	177°	208°	193°	180°	190°	197°	197°	204°	173°
	195°	190°	191°	199°	203°	207°	189°	178°	211°
	225°	166°	194°	207°	191°	193°	200°	189°	201°
	212°	171°	191°	203°	190°	211°	206°	207°	193°
	194°	180°	182°	191°	187°	199°	193°	211°	184°
	203°	214°	162°	211°	181°	200°	198°	208°	189°
	173°	193°	201°	198°	194°	189°	209°	194°	193°
	203°	204°	211°	203°	209°	185°	189°	192°	208°
	175°	194°	186°	187°	212°	201°	207°	182°	190°
	173°	173°	183°	175°	171°	193°	194°	195°	201°
	193°								
	187°								
Average:	190.8°	189.7°	197.4°	196.5°	193.7°	195.3°	196.7°	193.2°	195.4°

Table 4. 182 paleocurrent measurements, separated into columns by their relative measurement locations (see Figure 22 for location of the 9 measurement locations). The final row contains the average paleocurrent direction for each measurement location.

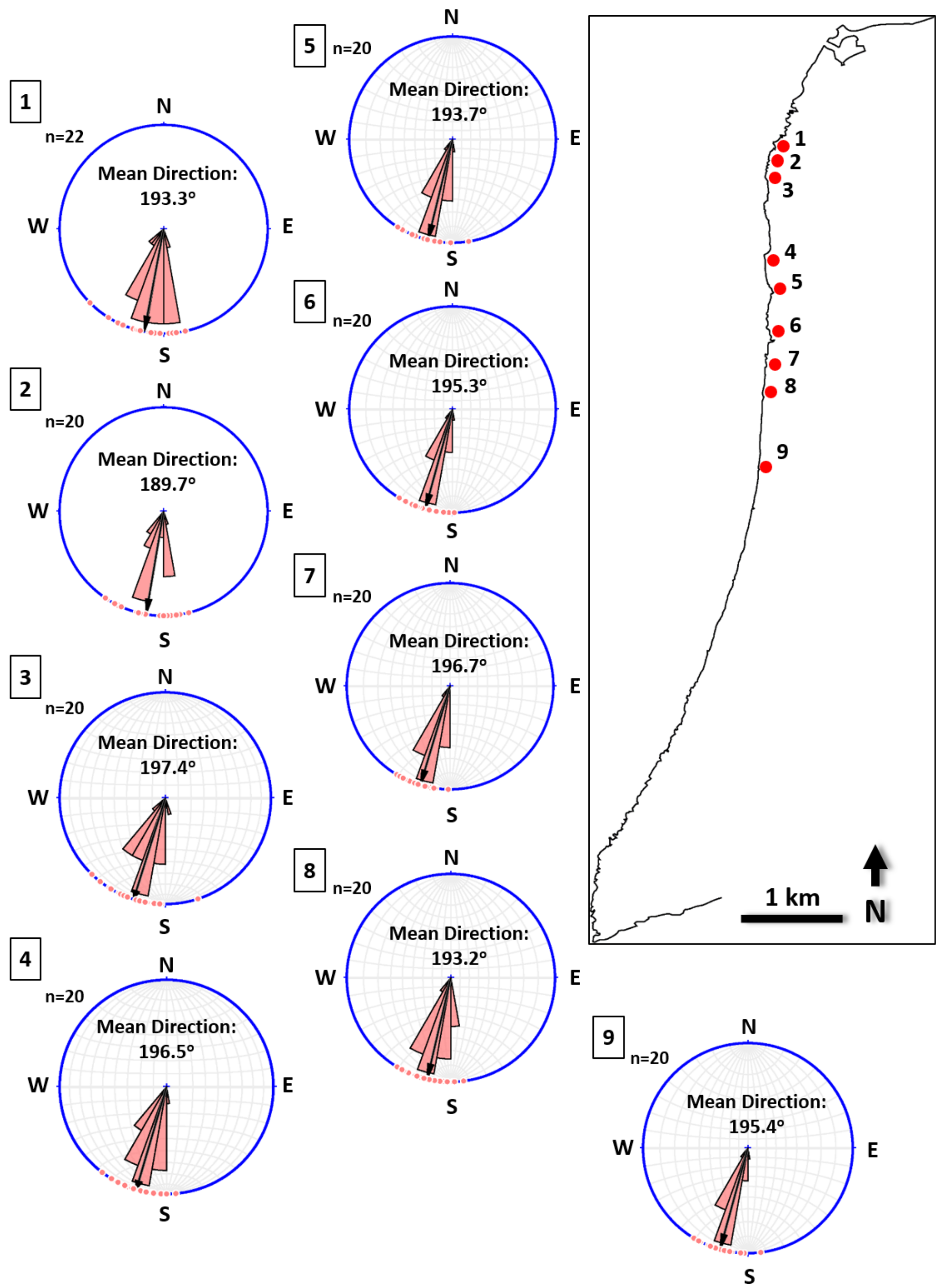


Figure 22. 182 paleocurrent measurements taken along the northwest coast show prevailing transport direction of the upper shoreface grainstones. 20 paleocurrent measurements taken at each of the 9 locations along the coast (with the exception of location 1, where 22 measurements were taken) were plotted onto rose diagrams. These diagrams show a southward, unimodal, longshore transport direction of the grainstones. Average current directions for each measurement location is plotted as a black arrow on each rose diagram; the average current direction of all 182 paleocurrent directions is 194.2°. Note there are no paleocurrent measurements south of point 9 because the upper shoreface becomes increasingly patchy in its distribution, and there is largely a lack of measureable troughs.

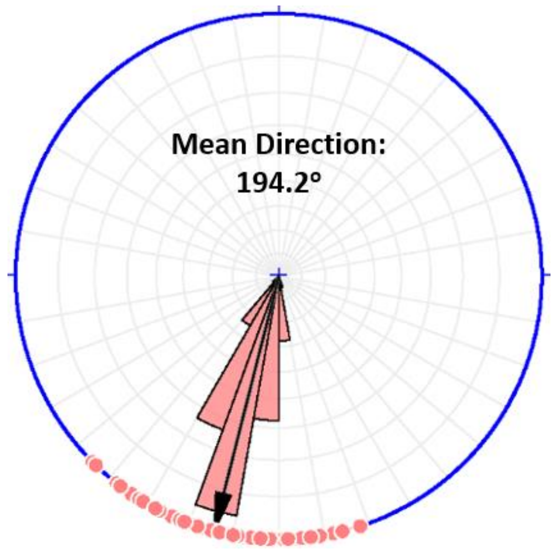


Figure 23. All 182 paleocurrent measurements plotted onto a single rose diagram, showing the composite paleoflow direction. The mean paleocurrent direction for all 182 measurements is 194.2°, with a range of 162°-225°.

VOLUMETRIC ANALYSIS

The total volume calculated for the leeward grainstones is 345,000 m^3. Accumulation rates were calculated using a constrained depositional period of 3 ky for the 5e_2 (Hearty 2002; Hearty et al. 2007; Kerans et al. 2015; Neumann and Hearty 1996) (Fig. 5). The 3D rate of accumulation for this strandplain is 115,000 m^3/ky. Several areas along the coast record as much as 6 meters of grainstone accumulation throughout the duration of the 5e_2; this corresponds with a vertical accumulation rate of up to 2 m/ky.

DISCUSSION

ACTIVATION OF THE SEDIMENT FACTORY

During periods of major carbonate platform flooding, such as the MIS 5e_2, production of oolitic sediment on the platform top is greater as a result of increased ocean water $CaCO_3$ saturation due to warmer ocean temperatures and enhanced platform top water circulation (Kindler and Hearty 1996). This study asserts that a rapid rise in sea level to +6 m at the end of MIS 5e (5e_2) time activated an ooid factory on the Caicos Platform; this ooid factory was the main source of western margin strandplain grainstones and played a large role in the growth of the leeward coast of West Caicos. Unlike MIS 5e_2, there is no evidence in the stratigraphy that shows this ooid shoal was active during the earlier MIS 5e_1 stage, when sea level was at +2 m higher than present day. MIS 5e_1 deposits along the leeward coast consist mostly of reef facies, and do not display the typical oolitic foreshore-upper shoreface facies successions associated with ooid shoal sourced strandplain systems (Kerans et al. 2015). The MIS 5e_1 deposits only aggrade to 2.5-3.0 meters above present day sea level; this is in direct agreement with the MIS 5e sea level curve, which pins sea level between +2 and +3 meters higher than present for the MIS 5e_1 (Fig. 5) (Hearty et al. 2007). Subsequently, there must be a critical water depth at which water circulation on the platform is great enough for this ooid factory on the Caicos platform to form and actively produce a significant volume of ooids to source the strandplain. Citing a lack of ooid production during MIS 5e_1 (Kerans et al. 2015), when sea level was +2 to +3 meters above present, and a rapid influx of ooid production during MIS 5e_2, when sea level was +4 to +6 meters above present, a water depth of +4 meters above present sea level is assigned as the critical water depth necessary to activate, or "turn on" the ooid factory on the Caicos platform.

Sediment transport

The unimodal, southward transport direction measured from the upper shoreface troughs indicate a northern provenance for the strandplain. At all 9 locations where significant paleocurrent measurements could be taken (20 per location), the average paleoflow direction did not waiver by more than a few degrees. These data support the assertion that grainstones were sourced from an ooid factory active on the Caicos platform during MIS 5e_2.

Another possible explanation for the formation of this strandplain unit is the leeward coast of West Caicos Island was an active ooid factory during MIS 5e_2 time. Formation of ooids in the foreshore-shoreface zone is well documented on Pleistocene-Holocene carbonate islands (Lloyd et al. 1987; Wanless and Rossinsky Jr 1986; Wanless and Tedesco 1993), but it is unlikely along the leeward margin for the following reasons. First, active ooid shoals need constant agitation through strong tidal or wind-driven water currents (Harris 1979; Wanless and Tedesco 1993); the leeward margin likely does not have the necessary energy for ooid precipitation. Second, the petrography indicates a fair amount of grain mixing, implying sediment transport over several kilometers. If an active ooid factory was forming along the leeward coast of West Caicos during 5e_2 time, there would be a more homogeneous (oolitic) grain distribution, and not such a high proportion of intraclasts, peloids, and skeletal material. Active forming ooid factories such as Ambergris ooid shoal (Jones and Awwiller 2008; Rankey et al. 2008), Long Road Beach (this study), and Long Bay Beach (Lloyd et al. 1987) show homogenous grain type distribution, with ooids making up >95% of all sediment from these three areas (Fig. 24).

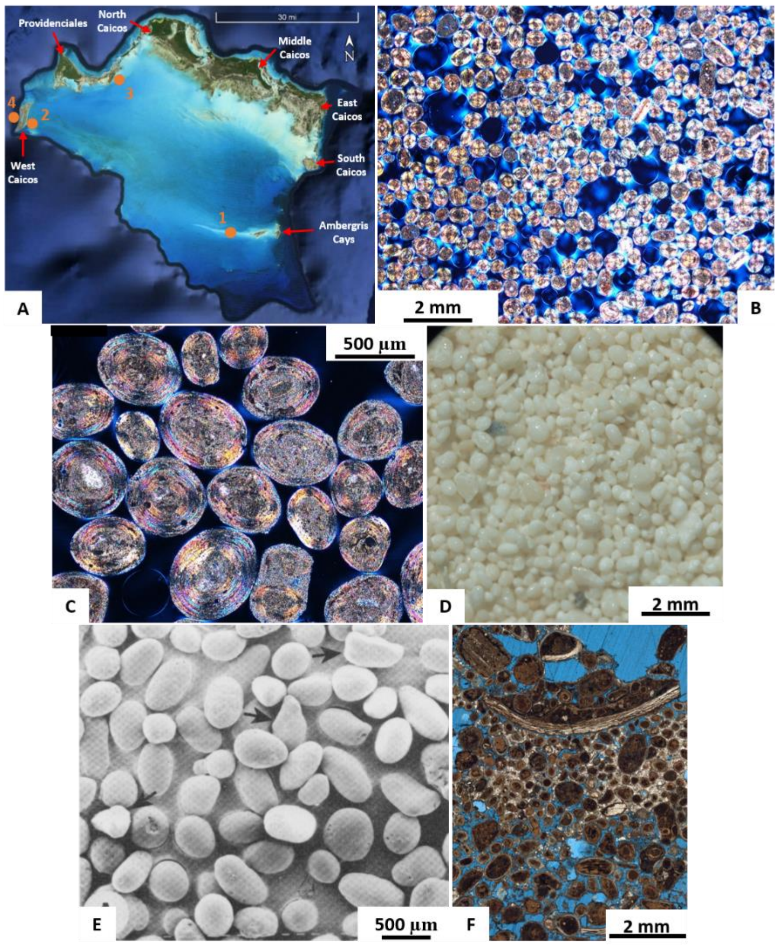


Figure 24. Petrographic comparison between various locations on the Caicos Platform. A) The 4 sampling locations on the Caicos Platform. B) Cross-polarized petrographic image of a thin section from Ambergris ooid shoal (location 1). The grain distribution from this actively forming ooid shoal is >95% oolitic. C) Cross-polarized petrographic image of a thin section from Ambergris ooid shoal showing internal structure of ooids. The ooids are concentric with the majority of them possessing peloidal nuclei. D) Microscope image showing grains from an ooid factory just offshore from Long Road Beach (location 2); this sample is dominantly oolitic, with >95% oolitic grains. E) SEM image of a sample from Long Bay Beach (location 3) taken by Lloyd et al. (1987). Similar to locations 1 and 2, this sampled area is dominantly oolitic, with only a few percent skeletal grains. F) Representative plain-polarized petrographic image from the leeward margin of West Caicos (location 4). Note the decrease in sorting and proportion of oolitic grains in comparison to locations 1, 2, and 3.

Note the decrease in sorting and proportion of oolitic grains along the leeward coast of West Caicos (location 4) in comparison to Ambergris, Long Road Beach, and Long Bay Beach (locations 1, 2, and 3). This supports the notion that the leeward margin MIS 5e_2 strandplain was not an actively forming ooid shoal, and that ooids were sourced from elsewhere on the platform. Third, the distribution along strike of the strandplain should not become increasingly thin and patchy as it moves south; this further supports the assertion that sediment supply of the strandplain lessened southward along the coast as distance from the northerly sediment source increased. Lastly, paleocurrent measurements demonstrate a unimodal, southward paleoflow direction for these strandplains, providing additional evidence of southward transport.

SEDIMENT DEPOSITION AND STRANDPLAIN FORMATION

Prior to deposition, a fair amount of sediment was likely winnowed off the western platform margin during transport due to prevailing easterly winds; nonetheless, longshore drift provided enough sediment for significant strandplain accumulation. Deposition along the leeward coast varies significantly from north to south, as evidenced by cross sections through Runway, Boat Cove, and Yankee Town. At Boat Cove and Runway(both northerly sections), the strandplain grainstone assemblages are up to 5-6 meters thick, and accumulate to a maximum of +6 meters above present sea level. Conversely, further south at Yankee Town, the strandplain grainstones assemblages are only 2 meters thick, and have poor continuity along strike. This discrepancy in strandplain thickness can be explained by an increasing distance from the ooid source. As the ooids are transported from north to south, an increasing fraction of ooids are winnowed off the platform and the strandplain becomes increasingly sediment starved; the platform margin is a mere 200 meters from the leeward coast of West Caicos. This decreases the amount of sediment which is transported to the southern half of the leeward coast, subsequently lessening the amount of strandplain deposition along the southwestern coast. Figure 25 is a cross section through the strandplain, and demonstrates the thinning nature of the foreshore-shoreface grainstones from north-south.

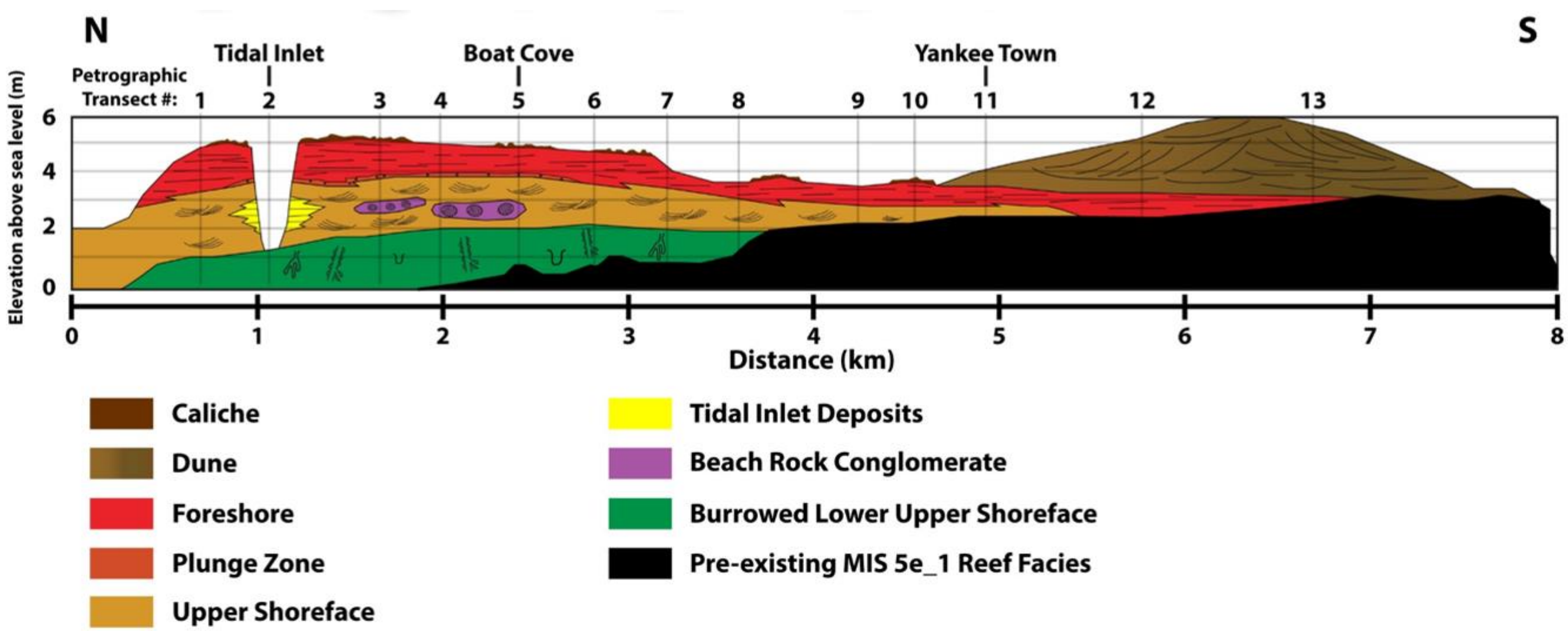


Figure 25. A cross section through the leeward strandplain, made from a compilation of measured sections, interpreted photopans and field observations from all 13 petrographic transect sampling locations. Note how the strandplain unit (foreshore-plunge zone-upper shoreface-burrowed lower upper shoreface) thins from north to south, and the pre-existing MIS 5e_1 reef unit thickens from north to south.

Widespread ooid shoal activation and deposition has been well-documented throughout the Caribbean during the latest Pleistocene (MIS 5e_2), indicating this sub-Milankovitch sea level fluctuation had a large scale effect on carbonate precipitation and sedimentation rates beyond the Caicos platform. Analogous to the island of West Caicos, the island of San Salvador is subject to similar easterly trade winds, and has a similar proximity to the leeward shelf margin. Strandplain grainstones have been documented along the leeward margin of San Salvador; these grainstones have a foreshore-shoreface facies progression and intraclastic-oolitic petrography similar to West Caicos, accumulate to approximately 5 meters above present sea level, and have been age dated to 120 kya (MIS 5e_2, Fernandez Bay Mb.) (Hearty and Kindler 1993). Late stage 5e deposits with similar facies successions have also been well documented on New Providence. Aurell et al. (1995) and Reid (2010) show an upper shoreface-plunge zone-foreshore facies succession at Clifton Pier that is akin to the facies succession at Boat Cove. Garrett and Gould (1984) also observe this facies succession on New Providence from core taken on the northern, exposed coastline, and from beach bar outcrops along the southern, protected coastline. The late MIS 5e beach facies of the southern, protected coastline are similar to Boat Cove in thickness and in average elevation above present sea level. These facies successions (such as Clifton Pier outcrop) are 4-5 meters thick, and are 4-5 meters above present sea level (Aurell et al. 1995; Garrett and Gould 1984). Jones and Hunter (1990) show the same facies progression with the Ironshore formation on Grand Cayman during the latest MIS 5e from heavily bioturbated lower upper shoreface grainstones to trough-cross-bedded upper shoreface grainstones to low-angle swash-stratified foreshore grainstones. Similarly to Boat Cove, this unit accumulates up to 5-6 meters above present day sea level, and contacts between facies tracts are at similar sea level elevations; the average contact between the foreshore and upper shoreface is 4 meters above present sea level, and the average contact between the upper shoreface and lower upper shoreface is 2 meters above present sea level (Jones and Hunter 1990). In Bermuda, Hearty (2002) presents an MIS 5e_2 unit called the Devonshire member of the Rocky Bay Formation. This unit has a similar facies succession to Boat Cove, and aggrades to 4-5 meters above present day sea level (Hearty 2002). This upper shoreface-plunge zone-foreshore facies succession from the latest MIS 5e has also been observed at Hole in the Wall on Abaco (Kindler and Hearty 1997; Walker et al. 2008), and Whale Point on Eleuthera (Hearty 1998). The MIS 5e_2 has a clear depositional facies succession which extends all throughout the Caribbean, well beyond the leeward margin of West Caicos. Nearly all studied Caribbean Pleistocene islands show evidence of MIS 5e_2 deposits (West Caicos, San Salvador, New Providence, Grand Cayman, Bermuda, Abaco, and Eleuthera) with a bioturbated lower upper shoreface, trough-cross-bedded upper shoreface, and low-angle swash-stratified foreshore. Most of these formations aggrade to 4-6 meters above present day sea level, indicating a maximum sea level of approximately +6 meters for the MIS 5e_2.

In addition to the diagnostic facies succession which represents the MIS 5e_2 throughout the Caribbean, the petrographic grain type distribution from the 5e_2 of West Caicos (this study) is similar to that of contemporaneous deposits on San Salvador (Hearty and Kindler 1993), Abaco, Bimini, New Providence, Eleuthera, and the Exumas (Kindler and Hearty 1996). Figure 26 shows a series of ternary diagrams showing the similarities in petrographic grain types between MIS 5e_2 deposits throughout the Caribbean; on all seven islands, MIS 5e_2 deposits have a highly oolitic-peloidal signal with a low amount of skeletal material. The data in this study from West Caicos for the MIS 5e_2 grainstones are in direct agreement with the Kindler and Hearty (1996) model, which suggests that during the MIS 5e, total flooding of carbonate platforms related to warm and humid conditions ramped up ooid and peloid production due to increased water circulation. This further supports the assertion that sub-Milankovitch sea level fluctuations can produced highstand deposits which are volumetrically significant components of Pleistocene-Holocene carbonate islands.

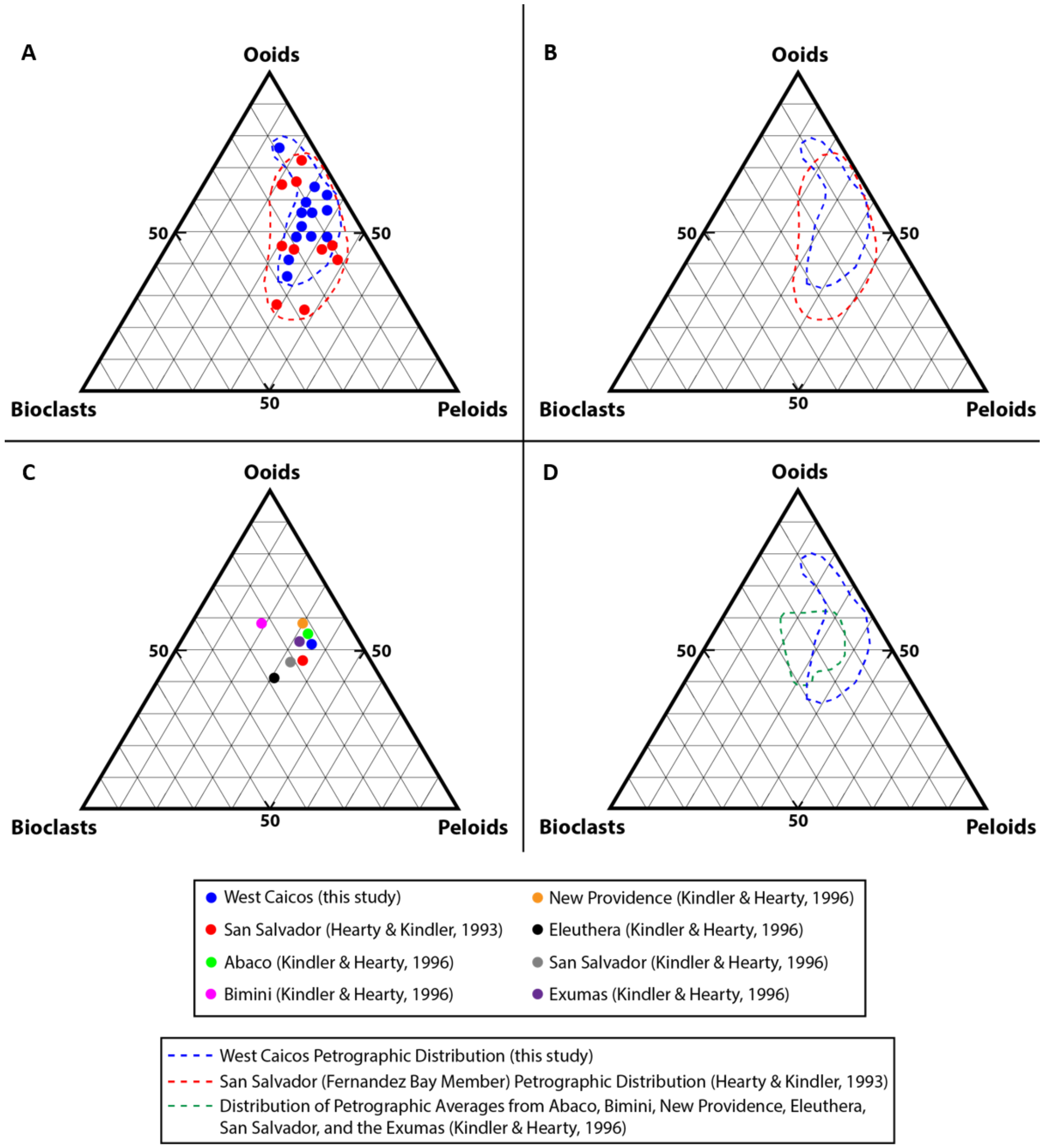


Figure 26. Petrographic comparison between West Caicos and various Pleistocene islands throughout the Caribbean. A) Ternary diagram showing grain type comparison (ooids vs. peloids vs. bioclasts) between the 5e_2 of West Caicos (this study) and the age equivalent Fernandez Bay Member from San Salvador (Hearty and Kindler 1993). B) Ternary diagram showing similar grain type distribution between the age equivalent West Caicos strandplain and Fernandez Bay Member of San Salvador. C) Ternary diagram showing average petrographic grain types for age-equivalent (MIS 5e_2) formations for West Caicos (this study), San Salvador (Hearty and Kindler 1993), Abaco, Bimini, New Providence, Eleuthera, San Salvador, and The Exumas (Kindler and Hearty 1996). D) Ternary diagram showing similar grain type distribution between age equivalent formations on West Caicos (this study) and Abaco, San Salvador, Bimini, New Providence, Eleuthera, and The Exumas (Kindler and Hearty 1996).

ACCUMULATION RATES

One-dimensional thickness accumulation rates on carbonate platforms have been studied in detail at rates in m/My (Bosscher and Schlager 1993; Eberli et al. 2002; Fischer et al. 2015; McNeill 2005; Schlager 1999; Schlager 2000). However, these rates focus on accumulation rates for entire carbonate platforms, rather than single geologic units. Rates of carbonate accumulation for a single strandplain constrained to a few thousand years do not exist. Understanding accumulation rates on the scale of thousands of years is important during global icehouse periods, when sea level is fluctuating rapidly at the scale of 100 kys, and carbonate deposition is constrained to several short-lived sea level highstands (Hearty and Kindler 1995). With necessary geologic maps and resources, it becomes possible to constrain accumulation rates for each sea level highstand; these accumulation rates unique to each MIS provide valuable insight into the accretionary history and evolution of carbonate strandplain islands such as West Caicos. In this case, vertical and volumetric accumulation rates of 2 m/ky and 115,000 m^3/ky, respectively, show significant accretion in a well constrained, sub-Milankovitch sea level highstand. While there are limitations to this volume calculation such as volume below sea level, coarseness of LIDAR sampling, and moderate age constraints, this initial volume calculation underscores the fact that small scale sea level fluctuations can have major effects on strandplain carbonate island building.

On a larger scale, outside of the scope of this study, formation rates for other Pleistocene-Holocene carbonate islands could be broken into singular geologic units or marine isotope stages; this would provide a more precise regional perspective on the accumulation history of Caribbean carbonate islands thoughout the previous 400 ky.

CONCLUSIONS

A +5 to +6 meter rise in sea level at the end of MIS 5e (5e_2) increased ooid production throughout the Caicos platform. While much of the sediment was likely winnowed off the western platform margin from currents influenced by prevailing easterly winds, as is going on during present day, some sediment was transported from north to south along the leeward coast of West Caicos via longshore transport, and approximately 345,000 m^3 was deposited along the west coast of West Caicos. This result is drawn from the following evidence:

1) 182 paleocurrent measurements from upper shoreface grainstones display a unimodal, southward paleoflow direction for the strandplain. This flow direction is perpendicular to paleo-shoreline, supporting the notion that they were transported by longshore currents.
2) Petrographic analysis shows no definitive trend in grain size and relatively consistent proportions of grain type in the north-south transects. The relatively uniform grain size and grain type trend across the strandplain profile shows a fair amount of grain mixing, indicative of transport over several kilometers.
3) Lateral facies continuity within the strandplain decreases to the south away from the proposed source. At Boat Cove (2 km down the coast), lateral facies continuity is exceptional, with select foreshore and upper shoreface deposits traceable for hundreds-of-meters along strike. At Yankee Town (3 km south of Boat Cove), lateral facies continuity is lessened, with few foreshore and upper shoreface beds traceable beyond a few tens-of-meters. The decrease is in part due to erosion, but

the decrease in facies volume supports the notion that these strandplain grainstones were sourced from a northerly ooid factory. Longshore processes were unable to distribute a large volume of grainstones along the southwest coast of West Caicos in the short time available for deposition, and the increased loss of ooids winnowed off the platform moving southward also contributed to this loss of volume.

4) The 5e_2 strandplain element decreases thickness along strike (north-south) as show in dip-oriented cross sections (Figs. 16E, 17F, 19F) and a strike-oriented cross section (Fig. 25), supporting the notion that fewer grains were deposited further south due to increased distance from the active sediment source.

These strandplain grainstones accumulated as much as 6 m of sediment in a 2-3 ky time period. The strandplain had an accumulation rate of 115,000 m^3/ky over a 3 ky period of deposition. These rates of accumulation support the notion that short-lived, sub-Milankovitch fluctuations in sea level can leave a stratigraphic record that could easily be interpreted as a complete precession cycle (20 ky) deposit. Furthermore, as this study shows, understanding the evolution, distribution, and accumulation of single, conformable carbonate strandplain is paramount, as they are the quintessential building blocks for interglacial Pleistocene-Holocene carbonate islands.

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